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INDIA RUBBER,

GUTTA-PERCHA, AND BALATA:

Occurrence, Geographical Distribution, and Cultivation of Rubber Plants; Manner of Obtaining and Preparing the Raw Materials, Modes of Working and Utilizing Them, Including Washing, Loss in Washing, Maceration, Mixing, Vulcanizing, Rubber and Gutta-Percha Compounds, Utilization of Waste, Balata, and Statistics of Commerce.

BY

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PREFACE.

IT is scarcely necessary to enter upon the importance of the rubber industry, or of the great trade in rubber which has now developed with all countries supplying the raw material—a trade which amounts to fully a million tons, worth more than $50,000,000 a year.

Owing to the peculiar physical and chemical properties of rubber, gutta percha, and balata, the industrial applications of these materials, and compounds of them, are becoming more and more extensive, and for some branches of industry, particularly electric engineering, they are indispensable.

Although rubber and gutta percha have been worked on a large scale for scarcely fifty years, the industry has developed with remarkable rapidity, and there are now numerous large factories exclusively engaged in working these useful materials.

The aim of this book is to give the reader a knowledge of the raw materials, as well as to present the industry in all its various branches as carried on by the most progressive manufacturers.

With this object in view all the available information has been brought together, and to make this information as complete and practical as possible the researches of the most eminent authorities have been consulted and drawn upon.

The book has been provided with a copious table of contents and a very full index, which will render any subject in it easy and prompt of reference.

W. T. B.

PHILADELPHIA, *March* 1, 1900.

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INDIA RUBBER, GUTTA PERCHA, BALATA.

I. INDIA RUBBER.

CHAPTER I.

RAW MATERIAL.

INDIA RUBBER, or caoutchouc,* is a product of the plant organism. Together with other solid and liquid bodies, it is very likely formed as a milky fluid in separate vessels by the conversion of tissue-mass, and, on the juice drying up, remains behind with other solid substances present. According to some botanists, it is a never-wanting constituent of every vegetable milky juice, occurring also in opium. The commercial article, however, is obtained from various trees of the tropical and semi-tropical regions.

Historical Review.

India rubber in the shape of bags and bottles was first brought to Europe in the commencement of the eighteenth century, but neither its nature nor origin was known. In 1735, La Condamine first

* Latin, *gummi elasticum;* German, *gummi;* French, *gomme;* Spanish, *seringa;* Portuguese, *xirringa.*

discovered that the substance was the dried milky juice of a tree, which the Indians on the coast of the Amazon River called *Caout-Chou*, and from which, from time immemorial, they had been making water-proof fabrics, shoes, vessels, etc. Fresneau, who had settled in Cayenne, described, in 1751, a tree yielding india rubber, and to this indefatigable explorer we are indebted for the first exact description of the method employed by the natives for obtaining it. The researches of La Condamine and Fresneau caused the French botanist Fuset-Aublet to make, in 1756, a journey to Guiana. Two years later he published his work on the Flora of Guiana, in which he described the rubber tree, and applied to it the name *Hevea guyanensis*. James Howison, a physician residing in Prince of Wales Island, an island of the Malay Archipelago, first determined the species yielding an "elastic gum wine," and Roxburgh later on applied the name *Urceola elastica* to this species. The latter also discovered in Assam, in the forest on the shores of the Brahmapootra, the *Ficus elastica*. Finally Coffigny described a vine-like plant of Madagascar belonging to the jasmine family, which also yields a milky juice. When dried this juice forms an elastic resin resembling rubber.

While the botanists studied the rubber-yielding plants, the chemists investigated the new resin, and succeeded in dissolving it. In 1768, Hérissant and Macquer communicated simultaneously to the Paris Academy the results of their investigations,

and called attention to the fact that india rubber, which is insoluble in water and alcohol, may be softened and even dissolved in oil of turpentine and pure ether. At the same time they proposed the employment of the softened resin for the manufacture of surgeons' probes and small tubes for use in the laboratory. The celebrated English chemist Priestley, in 1770, called the attention of scientists to the useful application of india rubber by recommending it for effacing lead-pencil marks. The experiments of the French chemist Berniard (1780) completed the labors of Hérissant and Macquer, and foreshadowed the many uses to which india rubber might be applied in the future. Faujas de St. Fond occupied himself in the investigation of a kind of resin found in the mines at Castelton, and called it *mineral caoutchouc.* Foucroy, Berthollet and Giobert also were interested in the study of india rubber. Grossart invented the most simple process of making from bottles of Brazilian rubber, tubes and other articles for physical and surgical purposes, as well as for household use. For the preparation of small tubes, he cut the bottles into strips of suitable size, softened them by placing them for half an hour in ether, or somewhat longer in volatile oil, rolled the strips upon a mandrel, and pressed them strongly by means of a rope wound spirally around them. On drying, the surfaces adhered together, and the pieces retained the shape given to them.

There may be mentioned here the more or less successful efforts of Besson (1791), Johnson (1797),

Champion (1811), and Clark (1815), to prepare water-proof garments by means of rubber solutions. But the actual rubber industry dates only from 1820. About this time Nadier invented a process of cutting rubber into threads, and of manufacturing tissues from the latter. Charles Makintosh, in 1823, used benzine for dissolving rubber, and created thereby the industry of the water-proof garments which are named after him.

But, nevertheless, the useful application of india rubber still presented many difficulties. The material was not easy to work, required special contrivances, and the still incomplete methods of dissolving it rendered it difficult to give definite shape to the articles.

These difficulties were overcome in 1836, when it was found, as the result of investigations by Thomas Hancock, that india rubber cut into strips, or passed between rolls and subjected to energetic kneading, can, under the influence of moderate heat, be converted into a tough mass; furthermore, that its elasticity is temporarily suspended, and that in this state it can be given any desired shape. By reason of these observations and discoveries, the industry made rapid progress.

However, the permanency of the industry would have been doubtful if it had not been for another invention of still greater importance than the preceding. Besides its impermeability and great elasticity, natural rubber possesses the property of being extraordinarily adhesive at an ordinary tempera-

ture, especially so when two pieces of it come in contact with each other. It shows this peculiarity to a still greater extent at a higher temperature, so that it becomes sticky and pitch-like, and diffuses a very disagreeable odor, but loses it entirely in the cold, it becoming brittle, and breaking when extended.

The German chemist Luedersdorf first noticed, in 1832, that sulphur deprives rubber dissolved in oil of turpentine of its stickiness. Hayward at the same time used flowers of sulphur for scattering upon rubber leaves, weakening thereby the adhesive power. Neither one of them, however, investigated the subject any further, and it remained for Charles Goodyear, in 1839, finally to settle the question of an india rubber useful in every respect, and to prepare a material which would not break at a lower temperature nor stick together at a higher.

The discovery of Goodyear consisted in that he first subjected the rubber to the action of sulphur, and then exposed it to quite a high temperature. This process is called *vulcanization*, and rubber thus treated, *vulcanized rubber*. Vulcanized rubber retains its elasticity at a high temperature (up to 248° F.) as well as at a low one (to —22° F.), and besides offers greater resistance to chemical influences.

The discovery of vulcanization gave great impetus to the rubber industry, and rendered possible its almost unlimited development, and in the succeeding twenty years nearly every day brought new

discoveries and improvements. Goodyear patented his process of vulcanizing by mechanical means, and, as early as 1842, brought rubber shoes into market which retained their elasticity in the cold, and hence were vulcanized. Shortly after Goodyear's discovery, Hancock succeeded after many experiments in preparing a product similar in all respects to Goodyear's. He immersed the rubber in melted sulphur, allowing it to remain until entirely permeated, and then exposed it to a temperature of 302° F. He patented this process in England in 1843. Parkes, in 1843, first employed carbon disulphide for dissolving rubber, and later on patented the method of "cold vulcanization," or vulcanizing by means of chloride of sulphur. He also invented the method of desulphurizing vulcanized rubber waste. In 1858, Augustin G. Day took out a patent for an improved method of vulcanizing, and Girard proposed alkaline sulphur for vulcanizing thin articles. The last great invention was that of *hard rubber* by Goodyear, who succeeded in obtaining a horn-like mass resembling whalebone or ivory.

Finally a patent may be mentioned which was granted to Hancock, in 1846, for the manufacture of rubber articles in moulds, an invention which, next to that of vulcanizing, has become the initiatory step towards the entire present manufacture of rubber articles, and has created an immense industry.

Occurrence of India Rubber.

As previously mentioned, some botanists claim that rubber is a constituent part of every vegetable milky juice. Many plants carrying milky juice are indigenous to temperate climates, but they contain either no rubber at all, or the quantity is so small that it would not be worth while to make an attempt to gain it on a large scale. It is claimed that the milky juice of milkweed (*Asclepias*) contains four per cent. of rubber, and some years ago a company was formed in Canada for the purpose of obtaining rubber from this source, but we have been unable to learn anything further in regard to this enterprise, and believe that the scheme has collapsed.

The habitat of the actual rubber-yielding plants is limited to tropical and semi-tropical regions between about the 30th degree of northern and the 30th degree of southern latitude. In these regions there extends around the globe, parallel with the equator, a belt nearly 500 miles in width, which possesses all the requisites for the propagation of rubber plants. The climate is warm and moist, the temperature varying between 79° and 107° F., and the average annual rain-fall being about 7 feet. The milky juice, or *latex* of the rubber plants of these regions is of about the density of cream, possesses a slight odor of amber, is miscible with water, but not with naphtha, nor with any other substance which dissolves rubber. Its specific gravity is from 1.02 to 1.11, while that of rubber is 0.930. There

is considerable variation in its content of pure rubber, the best quality of latex, that of Para, Brazil, having the following composition:

Pure rubber	32 per cent.
Albumen and mineral constituents	12 "
Water	50 "

The rubber plants may be arranged in four families as follows:

1. EUPHORBIACEÆ: *Hevea*, *Micranda*, *Manioc* or *Manihot*, *Euphorbia*.

a. *Hevea* is a variety of *Euphorbiaceæ* and belongs to the *Jatropheæ*: The tree is very large and contains much milky juice. It is readily propagated, the capsules containing the seeds bursting with a report like that of a rocket, and the seeds are scattered a distance of 50 to 60 feet.

Up to very recent times *Hevea Guyanensis* (called by Linné *Jatropa elastica*, and by Schreber, *Siphonia elastica*) has been incorrectly designated as the actual rubber tree called by the Indians of Brazil *Seringa* or *Cahuchu*. To be sure *Hevea Guyanensis* is the tree described by La Condamine and Fresneau, but it yields very little latex, which besides contains not much, and even not very good, rubber. The species of *Hevea* which yields the largest quantity and the best quality of rubber is *Hevea Brasiliensis* or *Siphonia Brasiliensis*.

b. *Micranda* (*Benth.*) is a tree-like *euphorbiacea* belonging to the *Jatropheæ*. It is indigenous to Brazil where three or four varieties are known to occur.

c. Manioc or *manihot* (*Plum-Adams*), a variety of *Jatropheæ.* Seventy-five species (herbs and shrubs) of it are indigenous to South America. The root is very rich in starch, and is an important article of food in the tropics. From *Manihot utilissima* and *M. Hipii* cassava and tapioca are prepared.

Manihot Glazowii or *leitera* yields the rubber known in commerce as *Ceara scraps*, called by the natives *manisoba.* It grows in dry, rocky soil on mountains, while *Hevea* flourishes in moist low lands and requires a clayey soil.

d. Euphorbia. This is a genus of many species, mostly shrubby, herbaceous succulents, affording an acrid milky juice which draws blisters. Thus far they have been but little utilized, but it may be supposed that in the future more energetic attempts will be made to obtain rubber from them.

2. ULMACEÆ, *a genus of Artocarpeæ:* Different varieties of *Castilloa, Ficus, Artocarpus* and *Cecropia.*

a. Castilloa, a variety of *Ulmaceæ* of the family *Artocarpeæ,* is indigenous to Mexico, U. S. of Columbia, entire Central America, the Antilles and Martinique.

b. Ficus belongs to the family of *Ulmaceæ,* division *Artocarpeæ.* The genus *Ficus* is very numerous, there being known more than 600 varieties which are indigenous to the tropical and warm moderate zones. Its widest distribution is in the Indian Archipelago and the islands of the Pacific Ocean. While *Castilloa* is the rubber tree of Mexico and Central America, the *Ficus* is the rub-

ber tree of East Asia and Australia. In Africa and America it is but seldom found.

Of the Ficus varieties, *Ficus elastica* is frequently seen here in hot houses, and is employed as an ornamental house-plant. It has large, leathery, oval and entire leaves, which are dark green and glossy above. It is readily propagated. A few shoots are allowed to grow until they have four or five leaves, and are then used in spring as cuttings. They are placed in a bottle full of water, and small white roots soon develop from the cut surfaces. The best soil for *Ficus elastica* is a mixture of leaf and wood mould.

c. Artocarpus is a tree belonging to the family *Ulmaceæ.* About twenty varieties of it are known to occur in Asia and Australia. The nearly ripe pistillate inflorescence, known as *bread fruit,* forms a globular sorosis about 6 inches in diameter, and consists of a mealy and spongy receptacle in which the oblong angular akenes are imbedded. The latex of *Artocarpus* is viscous, and is used by the natives in the preparation of bird-lime. The fruit forms an important article of food.

d. Cecropia (*Loefl.*) a variety of *Ulmaceæ* belonging to the *Conocephaleæ.* Indigenous to Central and South America.

3. Apocynaceæ: Varieties of *Landolphia, Urceola, Dijera, Hancornia, Cameraria, Parameria, Leuconotis, Artodendron, Alstonia* and *Chonemorphia.*

a. Vahea a genus of *Apocynaceæ,* which embraces about twenty species of lianas (climbing shrubs)

indigenous to Central Africa and Madagascar. The fruit is a large berry with eight-cornered seeds with hard perisperm.

b. Landolphia (*Pal. Beauv.*). This climbing shrub is generally considered a species of *Vahea*, but according to M. Radelkoffer, it is a separate species.

c. Urceola. This family comprises about six species of climbing shrubs indigenous to the Malayan Archipelago.

d. Hancornia. The various species of *Hancornia* are small trees containing milky juice. They are indigenous to South America, and yield a good quality of rubber. The fruits of *Hancornia speciosa* (*Gom.*) and of *H. Pubescens* (*Nees. and Mart.*) are known as *mangaba*, and are highly esteemed by the natives.

e. Cameraria (*Müller*) a variety of *Apocynaceæ*, order *Plumericeæ*, indigenous to the Antilles, are shrubs of which *C. lucida* and *C. latifolia* (*Jack*) yield rubber.

f. Parameria (*Benth.*), a variety of *Apocynaceæ-Nericeæ* and allied to the *Eidysanthereæ*. To this genus belong two or three climbing shrubs indigenous to Asia and tropical Oceanica. *Parameria Pierrei*, indigenous to Cambodia, yields excellent rubber.

g. Leuconotis (*Jack*) a variety of *Apocynaceæ-Carisseæ*. To this genus belong two shrubs containing milky juice, which are indigenous to the Malayan Archipelago.

h. Alstonia (*C.*), a beautiful tree indigenous to tropical Asia and Australia. The latex is very bitter.

i. Chonemorphia (*G.*), a plant of the variety *Apocynaceæ*, sub-division *Euechitideæ*. It is a vine-like climbing plant, three or four species of which are known to occur in the East Indies and in the Malayan Archipelago.

4. ASCLEPIADEÆ: *Callotropis*, *Cynanchum*, and *Periploca*.

a. Cynanchum (*L.*), a climbing plant of the family *Asclepiadeæ*, genus *Cynancheæ*, indigenous to Africa.

b. Periploca Græca (*L.*), a slender climbing shrub which contains milky juice, is indigenous to Africa.

c. Callotropis procera (*R. Br.*), a shrub 6 to 10 feet high, indigenous to Northern India and westward through Asia and tropical Africa. It carries beautiful large flowers of a rose and purple-red color.

It will be readily understood that the quantity of milky juice in the varieties of plants above enumerated not only varies, but is also dependent on the age of the plant, the nature of the soil, the season of the year, and even on the time of the year when it is obtained. It is also evident that the quality of the milky juice, and consequently of the rubber, depends on the manner in which the latex is obtained and the globules of rubber are separated.

While *Hevea brasliensis* must attain an age of at least 15 to 20 years before it can be tapped for milky juice, and reaches the height of productiveness when 25 years old, which to be sure it retains

to an age of 100 years, *Manioc* yields milky juice in 10 years, and *Urceola* even in 5 years. Climate exerts an important influence upon the quality as well as upon the quantity of the milky juice. Generally speaking, it may be said that the yield is remunerative only in the tropical zone, that is where the temperature varies between 68° and 104° F. In the temperate zone, between the 30° northern and 30° southern latitude, great variations occur, so that, for instance, a plant which flourishes exuberantly in Brazil, cannot be acclimatized in India. According to climatic conditions, the principal rubber plants may be arranged in the following geographical groups:

South America (plains): *Hevea, Micranda.*

South America (mountains): *Manioc, Hancornia.*

Central America: *Castilloa.*

West Africa: *Landolphia, Vahea, Callotropis.*

East and Central Africa: *Vahea, Landolphia.*

India: *Ficus, Willughbeia, Cynanchum, Cameraria, Chavonesia.*

Australia: *Ficus, Urceola.*

It has been generally supposed that all rubber plants require a moist soil exposed to the tropical sun. Such, however, is only the case with *Hevea brasiliensis*. *Hancornia* flourishes in the sandy tracts of Pernambuco, Maranham and Bahia, and *Manioc* upon the steep granite rock of Ceara or Clara. The last-named plants withstand even extraordinary drought. While everything else is destroyed by the hot wind, these plants flourish and yield an abundance of milky juice.

To be sure rubber plants grow most luxuriously where the soil is exposed to inundations or regular periods of rain. In a very wet season the milky juice is watery, and contains but little rubber, while in dry seasons the content of rubber is greater, but the quantity of milky juice less, and the work of obtaining the juice is more difficult. The content of rubber in the latex varies between 15 and 40 per cent. With a content of less than 15 per cent., the work of gathering the latex is not remunerative.

Cultivation.

It is obvious that in view of the growing importance of the rubber industry, attempts should have been made to acclimatize the rubber plants in other than their native countries. England took the initiatory steps in this direction, and experiments were made to acclimatize in her Asiatic colonies such varieties of plants as might prove suitable to the soil and climate, India being selected as the most promising field. The first experiments with an enclosed plantation were made in 1860 with the native *Ficus*, which produces a remunerative yield only after a growth of 25 years, and can be tapped only every three years. When fifty years old the *Ficus* tree yields every three years about 45 pounds of rubber.

This calculation, and especially the long time required before the tree becomes remunerative, did not hold out sufficient inducements; and besides, tests made in the meanwhile showed that the rubber ob-

tained was of inferior quality to that of Para and Ceara. Hence the further cultivation of this variety was discontinued.

Consideration was also given to the introduction of *Urceóla elastica*, which yields the first crop in its third year, and to *Urceolaesculenta*, which from its seventh year on yields one to four pounds of rubber, but it was claimed that *Castilloa elastica* would prove most remunerative, though its rubber is not of the first quality. In 1875, the administration of the Kew Botanical Garden authorized Robert Cross, a distinguished botanist and gardener, to make a journey to Central America for the purpose of studying the different varieties of *Castilloa*, with a view of introducing them in the English colonies. However, the plant, which flourished in the Kew hothouses in the hands of skilled gardeners, died in the open air, the moist climate of its native country where it rains nine months in the year being wanting.

In 1876, Cross was again commissioned to bring young plants of *Hevea brasiliensis* from the plains of the Amazon river. Though the natives jealously guard the trees in order to retain a monopoly of such an important industrial plant, Cross succeeded in shipping a number of *Hevea* to Kew. The result, however, was the same as with *Castilloa*. The tree to be sure grew in various kinds of soil, but reached luxuriant development only on the banks of running streams where a moist soil had not degenerated into a swamp. On the Amazon river ten days

seldom pass by without rain, and every morning the trees are enveloped in a heavy dew. The southern portion of Burma alone offers a climate approximately like it.

Beside the difficulties growing out of climatic differences, another important point had been left out of consideration in making these experiments. A country for the introduction of a rational cultivation of rubber trees to be carried on in an orderly manner, must be habitable, so that people can live there and stand continual, regular work. The territory of Assam which was selected for the experiments is just as little suited for habitation as the native country of *Castillio* and *Hevea*, the regions of the Amazon and of the San Juan, which only the Seringueiros, as the rubber gatherers are called, can penetrate during the so-called dry season, and where, exposed to fever and tormented by insects, they work and impatiently await the end of the harvest. These are the principal reasons which rendered a rational culture of these two trees impossible not only in India but also in America.

Acclimatizing experiments with *Manihot glaziovii* which yields the Ceara rubber were more successful. It requires a stony soil, and though it demands moisture, can stand great drought. Its habitat is the most mountainous and the roughest regions of Brazil, where a temperature of 77° to 86° F. prevails. It flourishes at a height of 6,000 feet above the sea, requires no special care, and readily adapts itself to the climatic conditions of its adopted country.

The seed coat is of remarkable thickness, and very hard, and the natural process of germination occupies, it is said, more than a year. All that is necessary to hasten this, is to assist the seed coat in splitting, which is best effected by holding the seed firmly and rasping off with a file both edges at the radicular end, recognized externally by possessing at its side a flat two-lobed appendage, technically known as the caruncle. It is best not to file off the actual end, as the radicle of the embryo may then be injured. After this treatment properly performed, the young plant appears above ground in two or three weeks. The seedlings require no particular attention. They grow rapidly and may be finally planted out at distances of 20 feet. Plantations may also be formed by cuttings, which take root as easily as a willow. They should be from the points of strong shoots, and about one foot in length. In planting, each shoot may be put down in the soil to a depth of six inches. On loose, sandy soil, or exhausted coffee land, plantations may be formed at little expense. Hard, dry gravelly wastes, if found to support any kind of bush, are also suitable sites. In strong land, holes may be made with an iron jumper, and a stout cutting put into each, and filled with pebbles. On bare or thinly covered portions of rock, the cuttings might be laid down flat, and a little heap of stones, or any kind of debris, about the size of a mole-hill, piled over each, care being taken that the extreme point of each cutting with a bud is left uncovered.

The habits of *Manihot* pointed it out as being well adapted for cultivation in Ceylon, and attention was concentrated on it as being the quickest growing, and promising not only early, but handsome returns. Several plantations were started in the Dumbara valley, and the returns of rubber were said to be profitable until it was found that the trees and their shade were inimical to the more important cacao trees underneath. According to the latest reports, the culture of *Manihot glaziovii* has been abandoned in the Java Botanical Gardens because "the promised magnificent results have in no respect been fulfilled."

According to a circular issued from the Royal Botanic Gardens, Peradeniya, by the Director, Mr. J. C. Willis, January 27, 1898, the only important rubber at the moment in Ceylon is the Para kind. The tree is well suited to the climate of the low country in the southwest of Ceylon, is readily cultivated, and gives a fair yield of rubber. *Hevea brasiliensis*, the botanical name of the Para rubber tree, forms a moderately tall tree, not much branched. The seed is very large, weighing about half an ounce. It has a hard seed coat, and the interior substance is very oily. The seed soon loses its power of germination, and ought to be sown within a week of its falling from the tree. Germination takes place very rapidly, and a long tap root is soon produced. The seed should be sown about an inch deep in well prepared soil, in nurseries, or, if preferred, in bamboo pots or baskets. They should

be kept shaded and watered, and when the young plants are from 18 to 24 inches high, they may be planted out. Good results are also obtained by stumping, the plants being allowed to grow about three feet high, then taken up, and the main root cut across about a foot below the ground, but the method of planting out the smaller seedlings is perhaps preferable.

The plant may also be propagated by cuttings. The method employed in the Botanical Gardens has usually been to take cuttings near the ends of the branches, but further back than any of the leaves. Each cutting is about a foot long, and as thick as a lead pencil, and is cut off at both ends by oblique cuts made just below leaf scars. This method is somewhat precarious; sometimes nearly all the cuttings grow, at other times only a small proportion.

The seedlings, stumps or cuttings should be planted out during rainy weather in prepared places. Holes should be dug and filled with good soil, a little manure being often of advantage. The young plants require to be lightly shaded for a time until they are established, and probably for the first two or three years they will grow the better for a certain amount of shade, such as would be given by narrow belts of trees running through the plantation. These belts should be arranged to act as wind belts, as the *Hevea* is easily injured by wind. By the time the trees are about three years old, they will have grown up to a height of about 25 or 30 feet, and form their own shade. Various distances

apart have been tried in planting *Hevea*, but the best results have been obtained by planting eight or ten feet apart each way. *Hevea* is a surface-feeding tree, and catch crops should not therefore be grown between the trees, which require all the nourishment that the soil can afford. Weeding is also required the first year or two, but afterwards the trees form a dense shade under which but few weeds grow.

The yield of rubber from very young or slender trees is too small to make their tapping worth while, and it is best for many reasons to abstain from tapping a tree until it has reached a girth of two feet. In a large plantation the girth of the trees always varies between wide limits. A few trees may be fit to tap after the sixth year, and in every subsequent year more and more trees will reach the size necessary. In favorable localities the bulk of the trees should be in bearing before the end of the eleventh year.

Experiments in the rational cultivation of rubber trees were also made in other countries, especially in the French colonies, for instance, on the Congo. In consequence of the irrational manner in which the natives treated the indigenous rubber plant, *Landolphia*, it was feared that in time it would entirely die out. E. Pierre, the creator of the botanical garden at Libreville, endeavored to prevent this danger by the acclimatization of foreign plants, and he also selected the *Manihot* as had been done in Ceylon. It would seem that the experiment has

been successful, Pierre reporting in regard to it as follows: "A single tree which I planted in 1887 has furnished up to the present time (1898) 115 trees. The plant, which M. de Brazza has endeavored to introduce as much as possible among the natives, has a great future for this country. The tree introduced in 1887 has already yielded 14,000 to 15,000 young plants, of which several thousand have been delivered to the natives in the remotest parts of the Congo territory."

The director of the garden at Libreville hopes to be able to distribute in a short time more than 200,000 young shoots for stocking new plantations.

On the other hand, a young French colonist, who has for some years resided in the interior, in N'Djolè on the Ogooué writes as follows: "It is true that the Pahouins have been furnished with young manihot plants, and explicit instructions regarding their cultivation have been given. But in most cases the natives have thrown away the shoots, and when not watched, continue in their barbaric destruction of the rubber trees. Why, if by penetrating a short distance into the interior they are assured of an easy and rich crop, should they undertake the laborious task of stocking a plantation, and wait for years for a crop which they may not live to gather and enjoy the benefits of? Hence it is not sufficient to lay out plantations and hand over the young trees to the natives. The care of these plants must be entrusted to the colonists in order to obtain favorable results."

According to Paroisse the *Manihot* cultivated in Libreville is not the one planted in Ceara and Ceylon, but a variety indigenous to an island on the south coast.

Acclimatizing experiments have also been made in Cochin-China, where the soil and climate are especially suitable for the cultivation of rubber plants. *Hevea guyanensis* has been successfully raised in the garden at Saïgon. But whether this enterprise will be crowned with better success than in the Kew garden remains to be seen. Experiments have also been made in Réunion.

Attempts towards a rational cultivation of rubber plants are now made in Peru, Columbia, Costa Rica, Mexico, and even in the Amazon River district, and nearly everywhere the success attained corresponds to the efforts made.

In Mexico a number of enterprising citizens are deeply interested in the project of starting rubber plantations, and as the soil and climate of portions of that country are suitable for that purpose, there is no doubt but that their efforts will be crowned with success.

Castilloa elastica is indigenous to the Isthmus of Tehuantepec, and particularly to that region lying near the Trinidad and Colorado rivers in the southeastern portions of the states of Vera Cruz and Oaxaca. In these districts it is found growing under varying conditions, though with certain limitations, for example: from sea level to an elevation of 1500 feet. In some localities there are, doubt-

less, exceptions where the tree may ascend the mountains 1000 feet higher. Careful observation justifies the belief that the zone wherein the tree attains its best development lies between sea level and 1500 feet altitude, and within a virgin forest district, with a mean annual temperature approximating 80° F. or a range of from 60° minimum to 95° maximum; also a well distributed rain fall approximating 100 inches per annum.

The trees are found growing in various soils, seldom in arid, gravelly districts, and when so found presenting a stunted appearance. They do not occur in swampy or inundated districts. They seem to prefer reddish clay soil where drainage is good, or black or reddish sandy loam. Occasionally they grow in rocky soil with deep deposits of of leaf mould, but only where there is much humidity and shade. They reach their finest development, however, in alluvial soils mixed or overlaid with dark forest loam, and in company with a fine growth of other trees, and more especially when the land is somewhat rolling in character, insuring proper drainage. In such land the wild trees exist in greater number near the sides of arroyos or streams, which rarely overflow their banks, though the trees near and on the summits of these rolling hills are quite as fine in development. Probably the greater number in the former case is owing to the fact that the seeds falling from trees above, are washed down and find lodgment in the more level places. Experiments in planting have demon-

strated equally as good growth away from the margins of streams as upon them.

The seed matures the early part of June, just about the beginning of the rainy season, and soon falls from the trees. Germination takes place very quickly in about ten days or two weeks. The vitality of the seeds is very short, and much disappointment will be met with by those planting seeds a few months old. The seeds should be gathered daily, when they commence to ripen, placed in a barrel with a gallon of water to about a peck of seeds. In eighteen hours fermentation will have sufficiently loosened the pulp, without injury to the germ, so that it can be washed off. The seeds should then be laid upon mats in a dry, but not too sunny position, for not longer than a week. They are then ready for planting. Under this plan 90 per cent. of seedlings may be procured. If gathered and allowed to remain in a mass for a week or more with the pulp on them, they generate a fierce heat, which utterly destroys the germ; while if washed and dried, as above stated, but not planted for two or three months, the yield of seedlings will be insignificant, if not a complete failure. The cotyledons undergo a rapid chemical change, leaving no nourishment for the germ. It is thus easy to see how a whole season may be lost in starting an enterprise of this kind.

Seeds planted in June may be transplated the end of August, and attain a height of three feet by the following June. From experiments made on the

Isthmus of Tehuantepec, it appears that the forest system of planting is more rational than the complete clearing of the land and planting in regular orchard form, as it entails less labor and expense, and affords the natural conditions of partial shade and a greater degree of humidity. These conditions do appear to be essential to the highest development of the tree and the greatest yield of sap. Hence this system involves simply the clearing of the under-growth and planting the seedlings at as nearly uniform distances as the standing forest will permit, only destroying such forest trees as are unnecessary to the fulfillment of the demands of shade and humidity, thus increasing the number of rubber trees per acre.

If, however, a regular plantation in regular orchard form is to be started, and the land set aside for the purpose is covered with trees, these must be felled, and the under-growth cleared only where the young trees are to be planted, providing no side planting is to be made. This work must be performed in the months of March and April, and immediately after Indian corn should be sown in the open spaces 15 inches apart. This operation is simply done by making a hole in the ground, dropping in a few grains, and covering over with the foot. Should the planter wish to adopt the most economic system, and thereby obtain the greatest return for the money invested, it would be advisable for him to plant besides corn, cotton, bananas and coffee. But the attempt to plant Mocha coffee must not be

made in elevations less than 1000 feet above sea level, neither on plains, nor where the temperature exceeds 85° F.

In the latter case the acreage to be planted must be stubbed, and the under-brush forked in or burnt before sowing the corn; then line and stake the plot in rows 15 feet apart. Peons who are posted in this kind of work, especially in coffee planting, have a long cord or rope—24 to 36 varas * in length—on which they mark the divisions with inks made from dye-woods in the forests in these sections. The cord is held by two men, and another one marks the holes with his garrocha, leaving a stake in the excavated place every 15 feet in the row. The rule of setting the trees at such distance would ensure larger size, and a greater flow of sap. As to shade, if the young plants have been taken from woods under shelter, then natural trees must be left on the plot before clearing to protect them from the strong rays of the sun until they are 10 or 12 feet high, and have a prosperous appearance.

This must not be overlooked, as the plant will suffer a great deal from transplanting even when that operation is done under the best of circumstances. But if the young plants are obtained from unsheltered places, or from a nursery established in an open space, they having grown stronger and stouter will require no shelter, and will flourish more rapidly and vigorously than if they had shade.

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* 1 vara = 32.9 inches.

If the seedlings or cuttings can be obtained within a few miles from a plot, it is advisable even to pay as much as $2.50 per 100 than to wait 12 months for the seed to grow in the nursery. When the place where the supply of young plants or cuttings is to be had is too distant, the expense of transportation would be enormous, and they would suffer to such an extent as to render them unfit and risky for transplanting. The only practical method in that case is to start a nursery. For this purpose a rich sandy loam should be selected. Beds are made 6 feet wide by 15 to 20 feet in length, leaving a walk 2 or 3 feet wide. The seeds are sown 8 inches apart in rows 10 inches distant one from another. This operation is done in the beginning of June or a few days after the rains have started, and by merely marking the ground, about an inch deep, with a stick, dropping the seed in, and covering it with vegetable mould.

In 12 months the seedlings are about 24 inches high and ready for transplanting. All weeds and grass must be carefully removed with the hand from the bed as they appear, and the earth watered when it seems dry, which is best done in the afternoon.

In the latter part of May or in the first days of June, when the rainy season commences, the seedlings, young plants or cuttings, are transplanted in the cleared plot between the corn and cotton, 15 feet each way. In removing the seedling or young plant, as much of the original soil as possible should

be left attached to it. The earth must be opened sufficiently to place the plant at the same depth as in the seed bed, and then press down the earth with a spade so as not to allow any hollows around the tree. The plot planted with rubber trees should be inspected now and then in order to judge how they are progressing, and to replace the plants that have withered and died. In July or August it will be necessary to clean the corn, weed the plot, and after harvesting the corn, banana suckers (hijos) can be planted 7 feet apart between the rows of rubber trees.

In Chiapas and Tabasco, cacao trees are set a few feet from the 2 or 3-year-old rubber trees, the latter acting as shade for the former in lieu of the regular madre protector or shade tree. Vanilla trees can be attached to the cacao tree, and by that means, after the lapse of 6 or 7 years, the planter has three or four different crops to harvest. Furthermore, bees could be raised on the place which would act as a medium to fertilize the vanilla flowers, and give a handsome profit from honey and beeswax. Again, should the proprietor not want any side planting, cattle, which bring a good income in those sections, may be permitted to graze on the land as soon as the young trees are well rooted and have grown over 20 feet in height. After going through the work of transplanting, the only care in the cultivation of the tree, thereafter, is that of keeping the ground free from all weeds and the rank vegetation of the tropics.

It is difficult to give the cost of establishing a rubber plantation, but it has been estimated that the entire expense for a plantation of 100,000 trees will not exceed 25,000 dollars Mexican currency.

Manner of obtaining Crude Rubber.

The quality of the crude rubber depends largely on the method employed in obtaining the latex, and the manner in which the rubber is separated from it. There are two methods of obtaining the milky juice, namely:

1. By cutting down the trees.
2. By tapping the trees by making incisions in the bark.

The first method—cutting down the trees—is still employed in Africa and Asia, and especially in the Indian Archipelago, where, within a few years, the Borneo rubber was only obtained in this manner. Generally speaking, this method must be condemned as irrational and destructive, though it might be permissible if the plants die anyhow in consequence of tapping, and in the case of trees which have to be removed in thinning out primitive forests. It is asserted by the natives of Peru that *Hancornia speciosa* dies in consequence of insects attacking the places where the incisions have been made. On the other hand, by cutting down the tree just above the ground, the stump soon sprouts again and throws out new shoots, so that in a few years there will be a group of trees where formerly was but a single tree.

Cutting down the trees for the purpose of thinning primitive forests is permissible if carried out in moderation and with judgment, it being useful, for instance, in the dense forests of Africa, since by the admission of air and light a more vigorous growth is promoted.

However, tapping by making incisions is the most rational manner of obtaining the sap, but care must be exercised to prevent injury to the trees. The method of tapping at present employed on the lower Amazon river is decidedly the best and most practical. The operation is as follows:

The Seringueiro, or as he is frequently called, the Cauchero, begins to work immediately at daybreak, or as soon as he can see to move among the trees. His tools consist of a machado—a small axe with a short handle and an edge a little over an inch wide—further a bucket and a number of small tin cups slightly concave on one side in order to fit the convexity of the tree trunk.

The trunk of the tree having been carefully cleansed, and the ground around the tree swept, the collector takes the axe in his right hand and, striking in an upward direction as high as he can reach, makes a deep upward sloping cut across the trunk, which always goes through the bark and penetrates an inch or more into the wood. The cut is an inch in breadth. In this manner each tree is tapped in twelve places. Some of the collectors arrange the incisions in the form of a V, and others in spirals, while others again simply

make them vertically, one above the other, from a point up to which they can reach with the hand down to a few inches above the ground.

The incisions having been made, the tin cups are fastened to the tree with a piece of kneaded clay, of which the Seringueiro carries a supply in his bag. One man is apportioned to a path or district containing 100 trees. When he has tapped and cupped his trees, he sits down at the end of the path for half an hour or so. As soon as he perceives that the tree last tapped has ceased to drip the milk, he starts at a trot on the back track, detaching and emptying the cups into his calabash as quickly as possible. The cups he leaves upside down at the base of the tree. Speed throughout is a great object, as the milk speedily coagulates. The quantity of milky juice obtained varies according to whether the tree is vigorous or decaying, but at an average each incision yields in one to three hours about 0.211 gill. The yield is, however, not the same every year, it being influenced by long continued rain and extraordinary drought, as well as by the incisions having been made either upon the sunny or shady side of the trunk. The latter circumstance explains the fact why some natives prefer tapping at nightfall. Besides, the natives assert that the milky juice is more abundant during full moon than at any other time.

The quantity of sap obtained from each tapping of 150 trees amounts to about 52 quarts of milky juice, or about 80 pounds of crude rubber. By

counting upon 20 tappings each year, the yield would represent a product of about 1600 pounds of crude rubber.

On the Upper Amazon tapping is effected in a similar manner, but the work is done less carefully, and the tools used are of a more primitive character. The further the collector penetrates into the virgin forest, the less baggage he wants to carry. A shell answers for a cup, and for the small machado the old-fashioned broad hatchet is substituted which has proved so destructive to the rubber trees.

With slight deviations. the method of tapping is the same throughout South America. The arrangement, number and depth of the incisions may vary, as well as the mode of harvesting, but the principle is the same.

In Central America, where *Castilloa elastica* is the principal rubber tree, a different treatment is required. The incision is replaced by a puncture, and is made with a smaller and finer tool than the machado.

In Africa, the operation of tapping is still carried on in an imperfect and irrational manner, almost every region having its own method. As a rule, the incisions are cut too deep, and in consequence of this the latex is mixed with other juices, which impairs the quality of the rubber, and the African product, which is naturally inferior to the South American, and especially to the Amazon rubber, becomes thereby of still less value.

In Asia, especially in the regions where the rub-

ber is obtained from the different varieties of *Ficus*, incisions of an elliptic shape extending to the inner bark or bast are made in the lower portion of the trunk and in the aerial roots. The yield of latex depends on the season of the year. While the quantity obtained in February and March is small, the content of rubber is considerable, and for this reason tapping during these months is most remunerative. The conditions are similar in August, when the content of rubber in the latex is 30 per cent., while in other months it decreases to 10 per cent.

In Australia the methods in use are generally the same for trees of a similar nature as in Asia, but the destructive method of felling the trees is also in vogue, especially where through the carelessness and shortsightedness of the authorities the matter is left to the natives themselves. *Urceola elastica* is especially subject to such thoughtless destruction. The stem of this climbing plant is cut up and the pieces are laid over large vessels for the sap to exude, and when the flow becomes slow, it is assisted by a brushwood fire.

Coagulation of the Latex.

The latex obtained by cutting down or by tapping the plants separates the rubber contained in it only when subjected to a particular method of coagulation which varies in every country, nay, in every province, and even from one side of a river to the other. Hence it frequently happens that there is a great variation in the quality of rubber

obtained from the same plant and in the same country, according to the coagulating process in use. Dr. F. von Hoehnel and James Collins have described the various methods of coagulation actually in use, and the following summary showing the various methods, and the countries in which they are employed, is based upon their researches:

The coagulation of the latex is effected:

I. By heat.

1. By artificial heat:
   - *a.* Dry heat or fumigation on the Amazon, in New Caledonia.
   - *b.* Moist heat, in Mexico, Central America.
2. By natural heat:
   - *a.* Separation of the serum by means of the soil, in Angola (Lower Guiana).
   - *b.* Separation of the serum by means of the human body, in Congo; Angola.
   - *c.* Evaporation upon even surfaces, in Ceara; Angola.

II. By skimming:

3. By skimming after increasing the fluid to double its quantity by the addition of water, in Bahia.
4. Skimming after a period of rest, addition of four to five parts of water, draining, washing and pressing, in Bahia; Congo.

III. By disintegration:

5. Chemical disintegration by means of reagents, Matto Grosso (interior of Brazil); Pernambuco; Maranham.

6. Chemical disintegration by the use of plants as reagents, in Peru ; Guatemala ; Nicaragua ; Gambia ; Madagascar ; Casamanza.

IV. By natural or artificial heat in combination with chemical disintegration, in Gambia; Senegal; Madagascar; Casamanza.

A brief description of the various processes of coagulation may be of interest.

Coagulation by artificial dry heat or fumigation. This method is especially suitable for the latex of *Hevea* and *Micranda,* and is chiefly employed on the Amazon in the preparation of Para rubber, which on account of its purity, durability and elasticity is highly prized and considered the best quality. This method, which is decidedly the best, however, is also employed in other parts of Brazil, as well as in Venezuela and Guiana, and is as follows:

The Seringueiro or rubber gatherer carefully removes from the tapped tree one cup after the other and empties the latex into a bucket or large bottle-gourd, which is covered with a wide-meshed net and provided with a rope handle. The empty cup is then again secured under the incision, which, however, is first carefully examined and opened if, as is frequently the case, it has been closed by the coagulation of latex. The thin skin of coagulated latex is removed from the incision and carefully laid aside. The sap from two or three trees will fill the bucket. If the hut of the Seringueiro is in the immediate neighborhood of the trees, the entire yield of latex is emptied without special care into a

large tub; but if the Seringueiro has to traverse a considerable distance before reaching his domicile, 3 per cent. of liquid ammonia is added to the latex to prevent coagulation on the road. The actual preparation of rubber, that is, fumigation, commences only when all the latex has been collected. For this purpose a fire of brush-wood is kindled, and on this a narrow funnel-shaped pot of clay, called *fumeiro*, is placed. When the smoke is of sufficient density, which the Seringueiro tests with his hand, palm nuts are thrown upon the fire, the nuts used being the fruits of the Urucury and Uauassu palms (*Attalea excelsa* and *Monicaria saxifera*) which, as a rule, can be had in the immediate neighborhood of where the work is carried on. However, nuts for the creation of smoke are only used on the Lower Amazon, where the best rubber is prepared, the smoke of brush-wood being considered sufficient in other regions.

When the smoke is of sufficient density, the Seringueiro, with the bucket of milky juice by his side, seats himself before the fire, dips a club-shaped piece of wood with a flattened clay mould at the end into the milk and turns the juicy end round and round in the smoke issuing from the pot. In half a minute the milk is changed into a skin of reddish tint. When this is firm the stick is again dipped into the milk, and so the process goes on, layer being added to layer, until a sufficient thickness has been obtained. Another stick is then taken up, and the work goes on until the juice has

been exhausted. A good workman can in this manner prepare in one hour five or six pounds of rubber. When the cakes are completed they are slit up with a sharp, wetted knife, and after being hung in the open air to dry for a few days, they are ready for sale. The flat rounded Para rubber cakes made in the manner described are known in commerce as "biscuits," and command a higher price than any other kind of rubber.

The most difficult portion of the process of preparing rubber according to the method above described is without doubt the operation of fumigating.

In order to understand thoroughly the efficiency of the process, a knowledge of the composition of the fresh latex is necessary. The milky juice of *Hevea* and *Micranda* from which Para rubber is prepared contains:

Rubber, ...	32 per cent.
Organic substances subject to putrefaction, and mineral substances, . .	12 per cent.
Water, ...	55–56 "
Liquid ammonia (added),	up to 3 "
Traces of resin.	

To be sure no other latex possesses such excellent qualities, but by taking into consideration the care exercised in collecting the sap, and in the separating process in order to prevent, on the one hand, loss in removing the watery constituents, and, on the other, to render innoxious the substances producing putrefaction and fermentation, it will be

evident that the superior quality of the rubber produced is more due to the excellent treatment than the quality of the milky juice.

The latex contains substances subject to putrefaction or fermentation whch may be fatal to the rubber. To render these substances innocuous, the natives have, instinctively, without any scientific knowledge, found the most simple means. First, by the repeated action of moderate heat the greater portion of the water contained in the serum is removed, whereby fermentation takes place almost instantaneously, but at the same time the incomplete combustion of the wood produces carbon, which is a very effective antiseptic, and cannot but exert a beneficial influence. Finally, by the combustion of wood creosote is evolved, which mixes with the smoke, and has also an antiseptic effect upon the nitrogenous substances. It is not positively known whether the smoke of the palm nuts mentioned above contributes to this antiseptic action, but it is alleged that its benefit consists in its absorption of the oxidized resin of the juice, and it is the smallness of the quantity of this resinous body in Para rubber that gives it the highest value in the markets of the world.

In connection with this an experiment may here be mentioned which may be considered an imitation of the process of coagulation in use on the Amazon, and which has been very successfully carried out by Grandjean and Waser in New Caledonia and the Loyalty Islands. In his work on "The Coloniza-

tion of the New Hebrides" (Paris, 1895), Dr. Davillé speaks in reference to this process as follows:

"The operation of tapping is very simple. Beside the Brazilian tin cup, a conical gutter tapering to a hollow prism, and provided on one end with a sharp blade, and on the other with a hook, is required. The blade effects the incision in the bark and serves at the same time for securing the gutter to the tree. The milky juice exuding passes through the gutter into the tin cup suspended to the hook. It is easy for the workman to suspend the cups in the morning, to empty them every three or four hours into a larger vessel, a bottle-gourd, or still better a tin can, and to replace them on the tree."

The further operations correspond to those on the Amazon river already described, and the result is an excellent and valuable quality of rubber.

It remains to mention a few details of the preparation of some kinds of Para rubber of less fine quality, namely, *Para Grossa, Para entrefina* and *Sernamby* or *Nigger-head.*

From the residues in the cups, or adhering to the lips of the incisions, a second quality of rubber is prepared by throwing them together and shaping into a flat ball. This ball is from time to time dipped in fresh latex, and after each such coating fumigated like fine Para. Finally it receives several coatings of fresh latex, so that externally it has the same appearance as the best quality of Para. However, this deception is readily discovered by cutting into it with a knife. This quality of rubber

contains a far greater quantity of water and a considerable amount of nitrogenous substances subject to putrefaction, the principal reason for this being that the skin of rubber taken from the incisions has been formed from the latex by the influence of natural heat. This process of coagulation will be fully described later on, and will explain the defects of *Para entrefina.*

Finally all the residues of less value from fine Para and *Para entrefina*—the scrapings from the moulding sticks, the residues in and around the vessels, etc.—are kneaded into blocks and packed into boxes or barrels. The whole mass sticks together, and acquires the shape of the receptacles. This rubber, which is, of course, of little value, is known as *Sernamby* or *Nigger-head.* It is very moist, frequently contains non-coagulated latex, even vegetable and mineral particles, and has not passed through an antiseptic process.

Coagulation of the latex by means of moist artificial heat or by boiling. This extremely primitive method is employed by the Indians of Mexico for the coagulation of the latex of *Castilloa.* The latex obtained by making an incision or puncture in the plant is collected in a piece of bark or in a pot, strained, and poured into a kettle under which a brushwood fire is lighted. As with animal milk, a layer of cream is formed under the influence of heat, which by continued boiling becomes solid, and can be separated from the watery constituents. In this manner pieces of rubber are obtained which, before they are

brought into commerce, are dried and pressed to deprive them as much as possible of moisture.

This process is evidently very defective. The mass is not sufficiently boiled to destroy all substances producing putrefaction and fermentation, the product is not subjected to sufficiently strong pressure to remove moisture, and finally, notwithstanding that the latex is strained, the treatment is not sufficiently careful to remove all vegetable and mineral impurities. In fact, experience has shown the correctness of this assertion, since on examining pieces of rubber prepared by boiling the blackish mass will be found to be full of bubbles filled with a thick, greenish liquid containing sand and splinters of wood. More recently a better quality of rubber also prepared from the latex of *Castilloa* has been introduced from Mexico. It is of a pale brown color, and of an agreeable odor, and contains neither sand nor other impurities. It is almost as firm as Brazil rubber, and the loss in working it is only 12 to 15 per cent. It has not been possible to ascertain the process by which this variety is prepared, but it may be assumed that the latex receives an addition of sea-salt. In British India, the latex is also boiled in preparing the Assam rubber obtained from *Ficus*.

Coagulation of the latex by natural heat. The soil as a means of separating water. Coagulation by natural heat is chiefly in use in East Africa. Although it is occasionally employed in other regions, it would, however, appear that all defective appliances,

which are the chief reasons of the inferior quality of the African product and its low price, are special characteristics of the natives of Africa, whose laziness is perhaps only surpassed by their rapacity.

The method employed by some tribes on the Congo and in Angola, who chiefly tap *Landolphia*, is, according to Jeannest, as follows:

The native taps a tree without caring whether it is destroyed thereby or not. The sap trickles down the trunk of the tree and falls upon the ground, the latter not having been even properly cleaned. The hot air immediately commences to absorb the water of the latex, so that the latter is half coagulated before it reaches the ground. The hot, dry ground absorbs the rest of the liquid, and nothing remains for the negro to do but to lift up the rubber. It is not worth while to criticise such a primitive method. However, the natives, instead of removing mineral impurities as much as possible, add them intentionally. Of course the soil, which in this process serves as a filter, can only absorb the fluid from the outer portions of the mass, since a skin is quickly formed upon the surface, which no longer allows the serum to pass through. In consequence of this, nitrogen, sugar, resin, etc., remain in the interior, the rubber is soft and sticky, and possesses an abominable odor, which, however, shows itself only later on. The loss in washing these varieties of rubber in the factory is very great.

Coagulation by natural heat; evaporation upon the human body. This very original method is also in

use by the natives of East Africa, and is decidedly preferable to the process above described. On the Congo, it is carried out, according to R. V. Merlon, as follows: Before tapping the plant, the negro divests himself of his very limited clothing, then makes an incision, catches the latex in his hands, and covers his entire body with it. Covered with this curious coating, he returns to his domicile. A crust is soon formed, which can be removed in patches, and is rolled into a ball.

According to Dr. Welwitsch, some tribes in Angola proceed in a similar manner. The negro presses his hand against the trunk of the tree immediately below the incision, and allows the exuding milky juice to run over his arm. When the coating is of sufficient thickness he, commencing at the elbow, draws the rubber off like a glove and rolls it up.

Although this method cannot be recommended, as the substances producing putrefaction are not destroyed, it has the advantage of no foreign substances being mixed with the latex. Evaporation of moisture is quite complete, as coagulation takes place in very thin, often repeated layers upon a large surface, the heat emanating from the human body also contributing essentially towards that end.

Coagulation by natural heat. Evaporation upon other even surfaces than the ground. This method is chiefly in use in Brazil in the preparation of Ceara rubber (Ceara scraps) which is obtained from *Manihot glazowii*, though the same method is also em-

ployed in several regions in West Africa and on the mainland of India.

In Ceara the operation is conducted as follows: The tree is tapped when about three years old, that is, when the trunk has a diameter of about 4½ to 5 inches. After cleaning the ground around the tree and spreading banana leaves for catching escaping milky juice, the Seringueiro makes in different places and in various directions slits in the bark from the foot of the tree up to a height of about five feet. The latex of *Manihot* being of much greater consistency than that of *Hevea* and *Micranda*, it exudes very slowly and seldom reaches the ground, most of it coagulating in the shape of long tears upon the bark of the tree, similar to resin on our trees. To allow it to dry, it is permitted to remain several days on the tree, when it is taken off in strips, folded together or rolled into a ball, and without further preparation, it is thus brought into commerce as Ceara scraps.

The rubber collected at the commencement of the harvest is of a blonde color, and represents the best quality. The second quality is of a darker brown color, and is gathered when the rainy season begins. The rubber collected at the foot of the tree constitutes the third quality, and is mixed, partly accidentally and partly intentionally, with earth and sand. The loss in working it frequently amounts to more than 50 per cent.

It is scarcely to be wondered at that rubber thus prepared contains a considerable quantity of min-

eral and vegetable constituents which considerably decrease its value. Ceara rubber has a beautiful amber color and is nearly transparent. The latter remarkable property, which, according to Morellet, is not possessed by any other variety of rubber, is claimed to be due to numerous holes in the interior of the mass through which the rays of light refract.

Ceara rubber has a strong odor, which becomes decidedly disagreeable on exposing the product to moist heat. The pure article gives in working 75 to 80 per cent. of rubber, and is quite resistant. There would be a larger demand for Ceara rubber if it were prepared with greater care and not adulterated by the addition of earth and other substances. The latex of Manihot is at least equal to, and perhaps superior to that of Hevea, as it contains fewer nitrogenous substances which produce fermentation, and considerably less water. However, the industrial result of pure rubber is only 75 to 80 per cent. Furthermore, Ceara scraps are difficult to keep, as in consequence of their content of substances producing putrefaction they require to be stored in a cool, dry place. While the treatment of the latex of Manihot, on account of its greater consistency, presents greater difficulty than that of Hevea, an improvement in the quality of the rubber might be attained by more suitable manipulation. Instead of allowing the milky juice to trickle down the trunk of the tree, it might be caught in cups and immediately mixed with alkaline water, it mixing in a fresh state better with this than with

pure water. In this manner the latex would be kept liquid for some time and fumigation might be employed for its coagulation. In Ceara, experiments of this kind have been made with excellent results, but unfortunately the natives will not listen to anything new, and continue their old, more rapid and less laborious method of preparation.

The Manihot grows upon the steep granite rocks of Brazil and yields only small quantities of very thick milky juice, but the tree flourishes also in the plains and in moist soil, in which case the latex is thinner and more abundant and could be readily subjected to the above-mentioned treatment.

Coagulation by skimming after the addition of the same quantity of water, and a shorter or longer rest. This mode of separation is employed in Bahia with the latex of *Hancornia,* in some regions of Nicaragua and Central America with the latex of *Castilloa,* and in Assam with the latex of *Ficus.*

In Bahia separation is effected by diluting the latex with water and allowing it to stand quietly for some time. Two layers, one above the other, are quickly formed, the upper one being butyraceous. When this has acquired sufficient consistency, it is skimmed off, dried, and thus brought into commerce.

In Assam the rubber prepared in this manner is placed in pots over a fire, whereby drying is accelerated. In Central America, the pieces of rubber are first rolled with wooden rolls to remove the excess of water and close the pores, and they are

then for fourteen days exposed to the sun to completely dry them, when they are rolled together and packed. These three modes of preparation are very primitive and of course the product can only be rubber of an inferior quality. The loss frequently amounts to 50 per cent., especially when the rubber is still fresh. It will be readily understood that this rubber is not in demand, though as regards elasticity and power of resistance, it is not inferior to other varieties.

Coagulation by rest after the addition of four to five times the quantity of water. This method is employed on the Congo for treating the latex of Landolphia, and has been described in detail by R. P. Merlon. With a sharp instrument incisions are made which penetrate the bark but do not touch the heart of the plant, as otherwise another kind of milky juice exudes which is acrid, very watery and spoils quickly. The incisions are made one above the other either in a straight or oblique line. Underneath the lowest incision is secured by means of rubber or clay a broad bent leaf, which catches the latex and conducts it to a bottle-gourd on the foot of the tree. The lower end of the bottle-gourd is provided with an opening which however is temporarily closed with a cork. The sap exuding from the plant is quite liquid and has the appearance of cow-milk thickened by long boiling. While in a fresh state it is mixed with four to five times its quantity of water, which accelerates coagulation, the rubber in the form of cream depositing on the surface. After twenty-four

hours the cork is removed from the opening in the lower end of the bottle-gourd, and the water together with the greater portion of the substances producing putrefaction runs off, while the rubber remains behind as a semi-fluid mass. For complete coagulation it is then poured into wooden vessels and for a few hours exposed to the air, whereby it acquires greater consistency but is not sufficiently solid. The mass is now kneaded. But as the lower portion has become too hard in the wooden vessel to be subjected to this manipulation, it is cut into small pieces or discs which in commerce are known as "thimbles."

The rubber thus prepared has the defect of containing quite a quantity of water and even undecomposed latex, and consequently substances producing fermentation, which soon impart to it a characteristically disagreeable odor. To overcome this evil the product is washed, which however is done in a very unsatisfactory manner. The rubber is spongy and full of holes which contain a whitish liquid producing the above-mentioned disagreeable odor. The loss in working it is frequently from 30 to 40 per cent.

From the latex of Landolphia other varieties of rubber are prepared which do not show the above-mentioned defects, and this proves that the small value of this product is due to irrational treatment.

Chemical disintegration by mineral reagents. This process being quick and not laborious, it is no wonder that its employment has rapidly extended

throughout Africa as well as America, Pernambuco, and Maranham rubber is now prepared in this manner, as well as several varieties on the Ivory Coast.

1. *Coagulation by alum.* This process is employed in Pernambuco for treating the milky juice of *Hancornia*, and is known as the Strauss process after its inventor, Heinrich Anton Strauss. A solution of potash-alum is added to the latex and coagulation takes place almost immediately. The mass is then placed for eight days upon hurdles to drain, when it is cut up, dried for a month in the sun and thus brought into commerce.

Strauss' process, according to Morellet, is very ingenious, but the results obtained are bad and do not justify the enthusiasm with which J. Collins speaks of it. He says: "This process, which has been purchased by the Pernambuco government, is an excellent one, and the more so as it is not necessary to employ it where the latex is gathered and coagulation takes place in the cold way."

The rubber prepared in this manner in time undergoes alteration, and when it becomes older, is changed into a mass of little market value. Although a piece of such rubber when fresh is quite elastic, it soon loses its elasticity, becomes stiff like pasteboard, and cannot bear mechanical manipulation. It becomes granular and brittle, and alum effloresces and crystallizes on the surface. When such rubber, which is of a rose-color inside and out, is cut up, quite a number of holes are found which contain not only serum, but also alum water used

for coagulation. By pressing, a portion of this alum water might be removed; but independent of the fact that the rubber-gatherer has not always a press at his disposal, evaporation would still be very incomplete and the injurious effect of the alum is not overcome. To be sure this mode of preparation is economical as regards labor, but the product suffers, and the loss in working it amounts frequently to as much as 60 per cent.

2. *Coagulation by sulphuric acid and sea salt.* In the provinces of Maranham and Matto Grosso, sulphuric acid diluted with water is substituted for alum. Like all other acids, sulphuric acid has the property of effecting coagulation, which, however, takes place so rapidly that there is not a sufficient evaporation of the water. In addition to this, acids have not an antiseptic effect and the product shows the same defects already mentioned.

Coagulation may further be effected by a solution of sea salt, and as its antiseptic action is well known it has generally replaced sulphuric acid in the two provinces mentioned above. Where sea salt cannot be obtained, the use of common salt might be recommended, which, however, leaves a larger quantity of water in the rubber. Some African varieties of rubber from the Ivory Coast, Cameroon and the Congo resemble these American varieties, and like them their preservation is chiefly due to the treatment with salt water.

3. *Coagulation by soap water.* This peculiar and remarkable method is occasionally employed in Peru

in the treatment of the latex of *Hancornia*. E. Bard describes the process as follows: "To coagulate the milky juice it is poured into large wooden vats or pits in the ground having a capacity of about 65 pounds of fluid. The soap has been previously dissolved in water, about four ounces of it being used for a bucketful of water, and two bucketfuls of this solution are considered sufficient for 65 pounds of latex. The soap solution having been poured into the latex, the mass is beaten with the hand, which accelerates coagulation. The rubber is formed in the shape of a block. To drain off the water the rubber is punctured in various places with a knife."

This rubber is of course very porous and contains a considerable quantity of water, and in consequence of the primitive treatment quite a number of foreign substances get into the mixture. It is difficult to understand the effect of the soap, and it may be supposed that the coagulation of the latex is promoted simply by the addition of water, which renders the latex more fluid and facilitates the separation of the globules of rubber from the serum.

It remains to mention here the experiments regarding the various methods of treating the latex of Hevea made by Dr. Morisse, a member of Count Bertier's expedition in 1888 to 1889 to the Upper Orinoco. Rousseau in his excellent article on rubber and gutta-percha gives a summary of these experiments as follows:

In his experiments to find an easy method for the coagulation of the latex without injury to the qual-

ity of the rubber, Dr. Morisse employed various agents with the following results:

One part of 90 per cent. alcohol coagulates six parts of rubber, the product being rubber of an excellent fine quality of a snow-white color which does not become yellow by age. On account of its costliness this method, of course, cannot be used for practical purposes.

Chloride of iron disintegrates the latex in the proportion of 1 : 9. The rubber thus obtained forms a coarse-grained dust, has a dirty color and but little coherence.

One part of alcoholic solution of corrosive sublimate disintegrates 11 parts of milky juice and yields a good quality of rubber.

One part of calcium chloride disintegrates 15 parts of latex, but it is difficult to keep this deliquescent salt in a climate where the air is always filled with moisture.

Chromic acid disintegrates the latex in the proportion of 1 : 5, while the action of nitric acid is still less effective.

Non-crystallized phenolsulphonic acid disintegrates the latex in the proportion of 1 : 18. The most effective agent, however, is sulphuric acid. Diluted with water in the proportion of 1 : 50, it suffices for the coagulation of 10 quarts of milky juice. It is even effective when diluted in the proportion of 1 : 100, but coagulation takes place only by agitating the mass, and besides requires considerable time.

Tincture of iodine appears to be effective only by reason of the alcohol it contains. Other preparations used in the experiments gave no remarkable results. There need be mentioned here only: potassium carbonate, bicarbonate of potash, carbonate of soda, common salt, potassium bromide, potassium iodide, ammonia, ether, chloroform, carbon disulphide, glycerine, arsenious acid, etc.

Alum, which has been successfully used for the latex of several rubber trees, gave only negative results with Hevea latex.

The first piece of rubber prepared with the assistance of sulphuric acid soon became spoiled by insects and cryptogamia, which rapidly developed inside and out. Dr. Morisse then concluded to mix the sulphuric acid with a powerful antiseptic agent and attained his object by the use of phenol-sulphonic acid. The last traces of this acid disappeared from the surface only six months after coagulation, but by that time the rubber was so thoroughly dried out as to leave no fear of injurious organizations. After numerous experiments, the following solutions were found to be most effective:

Solution A.	Phenol,	2.25 drachms.
	Alcohol, sufficient to dissolve above.	
	Water,	2 ozs. 13 drachms.
Solution B.	Sulphuric acid,	1.12 drachms.
	Water,	11.28 drachms.

Mix the two solutions before use. With slight agitation, the above quantity effects the instantaneous coagulation of one quart of milky juice.

In most cases a solution composed of 1 : 60 of the first and 1 : 30 of the second acid will be sufficient, but allowance must be made for the fact that coagulation is affected by the temperature, the hygrometric condition of the air, time of day, etc.

For the coagulation of 1000 quarts of milky juice, two quarts of sulphuric acid and four quarts of phenol are required, and hence the expense of the operation is very small.

From the quantity of milky juice above mentioned, about 220 pounds of Para rubber are obtained, which is dry, hard, resistant, solid and of good appearance, which proves the availability of this method.

From what has been said it will be seen that the latex of Hevea is not affected by some reagents which produce coagulation of the milky juice of other plants. Further, that the experiments to find in addition to the old method of fumigation, new processes of preparation are not promising, and the less so as experience has shown that rubber prepared by the addition of any kind of solution decreases in value."

Rousseau's conclusions will no doubt be accepted as correct. The excellent quality of Para rubber is due to the care exercised in its preparation, and to abandon the method would unavoidably cause considerable loss. Beside, the antiseptic effect of phenol appears very doubtful. Creosote alone can effect complete sterilization, and only when used after every layer, and under the influence of moderate heat.

Chemical disintegration by the addition of vegetable agents. This method is in use in Madagascar, Gambia, Peru, Guatemala and Nicagarua. In some cases a vegetable acid is added and in others an infusion, the chemical composition of which is not definitely known, but the action of which is very likely more or less due to the presence of a vegetable acid.

With the above mentioned African varieties of rubber, coagulation would seem to be effected by means of citric acid. Morellet says: "In examining Madagascar rubber, grains were frequently found which were recognized as seeds of *Aurantiaceæ.* It was at first difficult to understand how these seeds got into the rubber, but as they were found too frequently to allow of their presence being ascribed to accident, the conclusion was reached that the juice of *Aurantiaceæ* which contains citric acid was used for coagulation. This conclusion was later on confirmed by persons who had traveled in those regions."

Cousin asserts that while residing in Casamanza he had obtained by this method an amber-colored rubber, which was nearly transparent, of remarkable elasticity and durability. However this assertion is open to doubt, because while vegetable acids have the same defect as mineral acids of producing coagulation too rapidly, they are besides a natural breeding place of all kinds of microbes which produce putrefaction. This opinion is also confirmed by the fact that the use of citric acid for coagulation has been almost entirely abandoned in Madagascar, and sulphuric acid substituted for it. In Peru the co-

agulation of Hancornia latex is occasionally effected by means of a vegetable juice obtained from a climbing plant called by the natives *Sachacamote.* In Guatemala and Nicaragua the latex of Castilloa is treated in a similar manner. Coagulation is effected by an infusion of the root of *Ipomœa bona nox* which is widely distributed throughout Central America. In fact the milky juice is disintegrated by an organic acid not definitely determined, but later a resin is found in the rubber which not only decreases the industrial yield but is difficult to remove and troublesome in manufacturing. On the other hand the same latex with different treatment yields a very elastic, strong and profitable rubber.

Coagulation by a combination of natural or artificial heat with chemical disintegration. In Gambia (Casamanza, Ivory Coast) the method employed with *Valea* and other climbing plants is as follows: The rubber gatherer makes a slight incision in the plant and then bruises the bark somewhat. Every bruise is rubbed with salt water and the incisions, which are about 1¾ to 2⅓ inches long, are arranged so that there is an interval of about four inches between them. The latex immediately exudes as a thick white liquid. Under the influence of the salt solution the separation of serum and rubber takes place immediately, the globules of rubber running together and forming small lumps. The gatherer then takes a little rubber from each incision and combines these particles to a ball in his hand. But as the mass is very viscous, each portion neverthe-

less remains connected with the incision from which it exudes, so that a thread of rubber extends from each incision to the hand of the workman. The latter commences now to roll these threads, which are constantly formed by the uninterrupted exudation of latex, into a ball. In consequence of the extension and subsequent pressing between the fingers, the interior threads stick together as soon as they are covered by fresh threads, and the formation of threads is visible only on the outside, and unwinding of the ball is impossible. The bruises must of course, from time to time, be moistened with salt water. The rubber thus obtained is at first nearly white, but becomes darker in time and acquires a reddish color.

The weight of such balls varies between 9 and 28 ounces, though some weighing over 4½ pounds are also brought into commerce. Since the workman cannot hold these large balls between his fingers, to roll them up, he lies down on his back, places the ball upon his body, holds it with one hand and continues rolling until the plant is exhausted (Chapel).

This method, by which natural and artificial heat, together with a powerful antiseptic, act uninterruptedly upon very small quantities of rubber, can be highly recommended, especially where, on account of local conditions or the constitution of the latex, fumigation is not possible. Every single thread is also exposed to the air and the heat of the hand of the workman, which promotes the evaporation of the serum. To be sure the operation is rather labor-

ious. This method has another great advantage, namely that the product obtained is perfectly pure, it containing no vegetable or mineral admixture, except such as the workman intentionally adds. However, by doing so he hurts himself most, because if the trader's suspicion is once aroused, it becomes difficult and frequently even impossible to sell the product.

The various methods of coagulating crude rubber have now been described, and the result of experience and experiments up to the present time may be summarized as follows:

1. In choosing the method of coagulation the density of the milky juice must be taken into consideration. *Vahea* and *Manihot* yield thicker latex, and *Hevea*, *Castilloa*, *Landolphia* and *Ficus*, a more fluid one. Hence it would be incorrect to treat both kinds in the same manner.

2. Care must be had to produce rubber containing as little water and substances producing fermentation as possible. Further, efforts should be made to keep the rubber free from foreign substances, introduced either accidentally or intentionally, as such admixtures, independent of decreasing the value of the product, always give rise to suspicion of fraud. In this respect two methods can be especially recommended, namely, coagulation by fumigation and coagulation by artificial or natural heat with the addition of common salt.

3. The use of mineral and vegetable acids, as well as alum, and the addition of water, no matter in what form, always injures the quality of the product, and should, therefore, be avoided.

4. The shape in which rubber is stored is of importance. It has been observed that rubber keeps less well the larger the separate pieces are, especially when other fluids have been used in its preparation. This is readily explained, because the greater the surface presented the more moisture will evaporate, and the quality of the product is improved by drying out and the formation of putrefaction prevented.

5. The mixing of different kinds of milky juice should be avoided, since the inferior latex will injure the better kind so that the product becomes of less value and the quality is more or less altered.

6. A knowledge of the chemical composition of every kind of latex would considerably contribute towards determining the exact method to be used in every case; but unfortunately sufficient information in this respect is lacking, and it would be of great benefit to the rubber industry if chemists and naturalists would devote their attention to this subject. Adriani has endeavored to give an exact analysis of the latex of the Indian Ficus, and below the composition of Hevea latex will be given as accurately as possible, but regarding the composition of the milky juice of other rubber plants information is wanting. Such information, however, would be of great use not only in choosing the best mode of coagulation, but also for storing the different varieties of rubber.

7. A better knowledge of the milk vessels, their arrangement and development in reference to the other organs of the bark, would also be desirable.

But little attention has been paid to this subject, and such study would give valuable hints regarding the quality and treatment of rubber. Morellet has microscopically examined the bark of a few rubber plants and it would be well if his example were followed and the research extended to all rubber plants.

Chemical and Physical Properties of Crude Rubber.

Crude rubber as brought into commerce, being the inspissated or dried sap of certain varieties of plants, it will be necessary to consider first the fresh milky juice as it exudes from the plant, and for this purpose that of *Hevea brasiliensis*, being more or less typical, may be selected. It is a fluid which to the naked eye appears white, but in reality it is colorless, or at the utmost has a slight amber-color tinge. It contains a quantity of globular bodies with an average diameter of 3.5 micromillimeters.* These globules are the actual rubber, and though colorless themselves, they impart by their diffusion to the entire fluid a milk-white appearance.

The fresh latex of *Hevea* is odorless, but by exposure to the air it acquires, by the action of oxygen, an odor of methylamine,† which is found in all varieties of rubber not fumigated for the purpose of sterilization. The Para varieties of second quality, which consist of a mixture of fumigated and non-

* One micromillimeter is the thousandth part of a millimeter.

† A colorless gas, having an ammoniacal and slightly fishy odor.

fumigated rubber, also show this peculiar odor. The taste of fresh Havea milky juice is not pronounced, it being rather agreeable and sweetish than disagreeable and bitter. Its specific gravity is difficult to determine, it being affected by many accidental influences, but as a rule milky juice of less specific gravity is richer in elastic mass. The specific gravity of typical latex of *Hevea brasiliensis*, at a temperature of 58° F. is about 1.019, with a content of about 32 per cent. of rubber.

The chemical composition of the latex of *Hevea brasiliensis* as it exudes from the tree is as follows:

Elastic constituents . .	32 per cent.
Organic, nitrogenous constituents . . .	2.30 " "
Mineral salts . . .	9.70 " "
Resinous constituents .	traces.
Slightly alkaline water .	55–56 per cent.

The chemical and physical properties of crude rubber also show considerable variations according to its origin, mode of obtaining it and subsequent treatment. The better qualities have a more or less characteristic odor, that of fumigated varieties being not disagreeable and resembling the odor of smoked bacon. On the other hand, non-fumigated varieties and those of inferior quality containing water have frequently a disagreeable, and in many cases an offensive odor. The specific gravity is 0.92 to 0.96.

Crude rubber consists chiefly of a mixture of hydrocarbons, and according to some analyses it has the formula C_4H_7, or C_6H_{10}, or C_8H_8. However,

according to the most recent researches it is composed of $C_{45}H_{36}$. While this may be of little interest to the practical man, some varieties of rubber contain certain substances which deserve attention.

When rubber is treated with alcohol certain combinations are dissolved and are deposited in the form of crystals after the evaporation of the alcohol. The crystals dissolve readily in water, but there is considerable variation in their properties. By treating these combinations with solution of hydrogen iodide, they split into new bodies and not into fermentable varieties of sugar. The bodies soluble in alcohol have been called *dambonite*, *bornesite* and *matezite*, the first being found in African rubber, the second in Borneo rubber and the last in Madagascar rubber. Their composition is as follows:

Dambonite,	$C_4H_8O_3$	Dambose,	$C_3H_6O_3$
Bornesite,	$C_7H_{14}O_6$	Borneodambose,	$C_6H_{12}O_6$
Matezite,	$C_{10}H_{20}O_9$	Matezitedambose,	$C_9H_{18}O_9$

Although rubber is distinguished by its great chemical indifference, it is very sensitive to certain influences, especially to light, and oxygen and sulphur have great effect upon it.

That a change in the substance of rubber is produced by light, is shown by the following experiment: If rubber be exposed to the direct rays of the sun and then pressed upon a lithographic stone, the portion of the latter brought in contact with it will take and hold printing ink, while rubber not exposed to the sun fails to produce this effect.

If rubber be stored for a considerable time—several years—where it is exposed to the air, it suffers considerable change, at least on the surface. If such rubber be treated with a solvent, for instance benzene, a body is dissolved in the latter which remains behind after the evaporation of the solvent and shows the physical properties of a resin very rich in oxygen and not soluble in carbon disulphide nor in oil of turpentine—both solvents of rubber. This proves that by long-continued exposure to the air, partial oxidation of the rubber has taken place.

According to C. A. Burghardt, rubber gradually oxidizes, while a resin readily soluble in alkalies is formed which contains 27.3 per cent. of oxygen and besides a mass insoluble in alkalies and benzene is formed which contains up to 20 per cent. oxygen. Fresh vulcanized rubber contains three per cent. of the first resin, but none of the latter.

By coating rubber with oil, especially olive or palm oil, its destruction is accelerated, because these bodies promote the action of oxygen. Rubber brought in contact with copper or copper combinations is also rapidly ruined. Rubber to which in vulcanizing an excess—more than 2 to 2½ per cent. —of sulphur has been added is quickly destroyed by the sulphuric acid formed from the sulphur.

The content of water in good rubber amounts to only 0.5 per cent., while old rubber articles which have become hard contain 5 to 10 per cent., which escapes completely only at 248° F.

When rubber becomes hard and brittle, a chemi-

cal change evidently takes place, the content of carbon decreasing, as shown by the following analyses by Burghardt:

	I.	II.	III.	IV.	V.
Carbon	77.91	72.53	70.43	65.09	64.00
Hydrogen . . .	10.33	11.31	10.59	10.00	9.26
Sulphur	5.15	1.97	3.14	1.95	2.28
Oxygen	6.61	14.19	15.84	22.96	24.46

No. I was good material, but contained too much sulphur; Nos. II, III and IV were more or less brittle, and No. V very hard and brittle.

Neither cold nor warm water dissolves rubber, but boiling water extracts from some varieties a resin-like substance. In warm water it becomes very soft and swells up considerably, dark pieces becoming lighter and the whole mass more susceptible to solvents; but on being exposed to the air for some time, the normal condition is restored. The pale color of light, opaque varieties of rubber is due to a content of water; after drying, they are transparent and dark.

Rubber is capable of absorbing as much as 18 per cent. of its weight of water, its volume at the same time increasing to as much as 10 per cent.

Behavior towards sulphur. The behavior of rubber towards sulphur is of great interest to the manufacturer. Brought in contact with melted sulphur, it absorbs it very freely and, according to the quantity of sulphur used and the temperature to which the mixture is heated, two substances are produced showing very different properties.

If rubber is treated with a *small* quantity of sulphur and the mixture heated for a short time, a gray substance is obtained possessing great elasticity, which does not vary much even under changes of temperature. The product thus formed is known as *vulcanized rubber* or *vulcanite.*

But if rubber is treated with a *large* quantity of sulphur at a high temperature for a considerable time, it gradually acquires properties entirely different from its original ones. It is black, possesses but little elasticity, and as regards its physical properties, may be best compared with horn. This substance is known as *hard rubber* or *ebonite.*

Behavior towards solvents. Solutions of rubber are of great importance for many industrial purposes, the manufacture of water-proof tissues, of rubber lacquers and varnishes, etc., depending on them. The behavior of rubber towards solvents is different from that of most substances, which are either soluble or insoluble, and in this respect it very much resembles resins. Although not soluble by certain agents, it will swell up when brought in contact with them, and thereby acquire the property of being soluble in many substances to which otherwise it is entirely indifferent.

In many solvents, for instance, in a mixture of alcohol and carbon disulphide, rubber swells up to thirty times its original volume, and in preparing solutions of it, this must be taken into consideration.

Among the substances capable of dissolving rub-

ber in the actual sense of the word may be mentioned: Ether, benzene, oil of turpentine, essential oils, and tar oils in general, as well as caoutchoucine, an oily product obtained by the destructive distillation of rubber. Fat oils heated to a high temperature will also dissolve it, but it is questionable whether the resulting products can be actually considered as solutions of unaltered rubber.

However, the substances named above are not capable of holding the entire mass in solution, and can absorb only a certain proportion of it. To obtain the best solutions, the rubber, as well as the solvent, should be as free from water as possible, and two solvents should be used, allowing the rubber to swell up in one and then dissolving it in the other. Some experiments have been made as to the solubility of different varieties of rubber, the solvents used being entirely free from water and the rubber having been previously dried for one week over sulphuric acid. These experiments, as shown by the results given below, prove that different varieties are soluble in various proportions.

Of 100 parts of dried rubber were dissolved:

In carbon disulphide .	65 to 70 parts.
In benzene . . .	48 to 52 "
In oil of turpentine . .	50 to 52 "
In caoutchoucine . .	53 to 55 "
In ether	60 to 68 "

If the solutions are allowed to evaporate, a colorless mass of considerable elasticity is left behind, which, however, does not possess all the properties

of rubber, its behavior differing from the latter, especially when subjected to heat.

According to T. F. Hanausek:

			Ceara rubber. Parts.	Nigger-head. Parts.	Sierra Leone. Parts.
100 parts of	ether	dissolve	2.6	3.6	4.5
" "	oil of turpentine .	"	4.5	5.0	4.6
" "	chloroform . . .	"	3.0	3.7	3.0
" "	benzene	"	1.5	4.5	4.0
" "	carbon disulphide	"	0.4	—	—

The portion of the rubber which remained behind after repeated treatment with the above-mentioned solvents, showed a brown color similar to that of the product originally used, possessed little elasticity but considerable tenacity. When examined with a microscope, immediately after treatment with the solvent, it appears like a wide-meshed net, but in drying it contracts considerably.

As has previously been mentioned, to effect a complete solution of rubber requires certain manipulation, and may be best done as follows: Allow the rubber to swell up in carbon disulphide, which is most rapidly effected in a closed tank in a moderately warm place. Then add 10 parts of absolute alcohol for every 100 parts of carbon disulphide used. Solution will be complete in a few days, and by allowing the mass to stand quietly for a sufficient length of time, all foreign admixtures will settle on the bottom.

By mixing the solution with a large quantity of alcohol, the rubber is again precipitated in a spongy

form, while the foreign substances remain in solution. By pouring off the brownish solution from the precipitate and repeating the same operation several times, the rubber is obtained free from coloring matter, as an entirely white mass, or showing at the utmost only a slightly yellowish color.

The use of carbon disulphide as a solvent is, however, objectionable, on account of its great volatility and also its poisonous fumes, and oil of turpentine is, therefore, recommended as a substitute for the preparation of rubber solutions. But the ordinary commercial oil of turpentine always contains a considerable percentage of water, and does not effect complete solution. Hence, for the preparation of large quantities of solution, it is advisable to free the oil of turpentine from water, which may be effected in various ways. The simplest plan is to pour it, together with about 10 per cent. of its weight of sulphuric acid, into a tank, cover the latter tightly, and let it stand quietly until the solvent is to be used. The sulphuric acid forms a sediment on the bottom of the tank, from which the oil of turpentine can be readily drawn off. In place of sulphuric acid, fused calcium chloride can be used with equal success.

For the treatment of larger quantities of oil of turpentine, it is advisable to rectify it over quicklime and to pass the vapor, before it condenses, through a nearly red-hot pipe. By this process, the character of the oil of turpentine is much improved, and it is much better adapted as a solvent.

The solution of rubber is readily effected by cutting it into small pieces and placing them in linseed oil heated to a point, when it throws out heavy vapors and is in a state of ebullition. But it is scarcely possible that in a solution thus prepared there is any unaltered rubber, and it is very likely that it only contains products of decomposition of it. For certain purposes such solution is, however, very useful. When applied in a thin layer to an article and exposed to the air, it dries to a transparent layer distinguished by great tenacity.

Caoutchoucine, or oil of caoutchouc, which, as previously mentioned, is obtained by destructive distillation of rubber, has been recommended as a solvent without, however, being especially suitable for the purpose. Its power of dissolving rubber is only slightly greater than that of anhydrous oil of turpentine, and the cost of producing it is comparatively great.

It would seem that for practical purposes the most suitable solvents are carbon disulphide in combination with absolute alcohol, and anhydrous oil of turpentine. To be sure, benzene and coal-tar oil are also good solvents, but they have the disadvantage that their disagreeable odor adheres for a long time and very tenaciously to the rubber. Lascelles recommends 92 per cent. benzene and 4 to 8 per cent. of eucalyptus oil as a solvent.

In case solution is to be effected by means of carbon disulphide and absolute alcohol, it is advisable for the manufacturer to prepare the latter him-

self, which may be done as follows: Bring 95 to 96 per cent. alcohol into a flask previously filled about one-fifth full with blue vitriol which has been heated to such a degree that the blue color has been changed to white. The vitriol absorbs all traces of water from the alcohol whereby it gradually reassumes its original blue color, while the supernatant alcohol has become entirely anhydrous, *i. e.*, absolute alcohol.

According to C. Fry's patented method solutions of rubber and gutta-percha can, it is claimed, be prepared with great facility if the solvent—coal-tar oil or oil of turpentine—is distilled with a small quantity of rubber or gutta-percha. The crude oil is brought into a still, and to each 11 lbs. of it are added 6½ to 9 ozs. of rubber or gutta percha.

The solvent is distilled off, and the residue remaining in the still used for producing coarser tissues. It is claimed that solvents prepared in this manner are best adapted for the solution of rubber and gutta percha. If such be actually the case their superiority is very likely due to an admixture of decomposed products of rubber, many of them being excellent solvents of the latter. It has also been suggested to distil rectified spirits with rubber in the same manner as described, the dissolving power, it is claimed, being thereby considerably increased. However, since petroleum has come into use for preparing rubber solutions, which will be referred to later on, and as carbon disulphide and the light tar oils can be procured at very

low prices, the question as to solvents for rubber has lost much of the importance it formerly possessed, and at the present time rubber solutions of any desired consistency are readily prepared.

Behavior in heat. At 50° F. rubber is comparatively solid, and not very elastic, at 96.8° F. it is soft and elastic to a high degree; gradual increase of heat decreases the elasticity, and at 248° F. it liquefies and emits a peculiar odor. When it has been heated to the melting point it congeals on cooling to a mass, which remains sticky for a long time. If exposed to a still greater heat, it ignites and is consumed with a bright and sooty flame.

But if treated at a high temperature in a closed vessel, that is, if it is subjected to destructive distillation, there is obtained, besides the coal which is deposited, a quantity of gas, and a fluid called oil of caoutchouc, which, as has been stated, is a solvent for rubber.

The crude oil of caoutchouc (caoutchoucine) gained by destructive distillation, is a mixture of several combinations of hydrocarbons, some of which are characteristic of rubber, while others appear also in the destructive distillation of other organic substances.

By heating rubber in vacuum to a temperature above 392° F. a mixture of isoprene, caoutchene and heveene is formed. Gladstone and Hilbert have adopted for these combinations the following compositions:

Rubber	${}_{n}C_6C_4H_{16}$
Isoprene	C_4CH_8
Caoutchene	$C_4C_6H_{16}$
Heveene	${}_{n}C_2C_3H_8$

The following bodies have thus far been determined as being present in oil of caoutchouc: Eupione, butylene, caoutchin, caoutchene or dipentene, isoprene and heveene. Caoutchin forms at —0.4° F. a white crystalline mass consisting of needles which at 14° F. fuses to a transparent oil and boils at 58.5° F. Isoprene is a water-clear, very mobile liquid which boils between 98.5° and 100.5° F. By the admission of air it loses its fluidity, becomes sticky and absorbs ozonized oxygen with avidity. Eupione, butylene and isoprene are chiefly found in the portion of the distillate which passes over first, and must be collected in vessels thoroughly cooled off.

The greater portion of caoutchene is found in the part of the distillate which passes over between 284° and 536° F. When pure it boils at 339.8° F., and, what is very remarkable, congeals only at a temperature below —40° F. It also absorbs oxygen with avidity.

Heveene, which is contained in the last portions of the distillate passing over, is an amber-colored oil, of specific gravity 0.92 at 70° F. It boils at 599° F., does not congeal in the cold, has a slightly empyreumatic odor, an acrid taste, and consists of 86.11 per cent. carbon and 14.02 per cent. hydrogen.

According to Bouchardat, 11 lbs. of fresh Para rubber yield 8.81 ozs. isoprene, 70½ ozs. caoutchene

(dipentene), and 21.16 ozs. heveene. There are formed besides, polyterpenes boiling at a higher temperature than heveene and only a small quantity of gases, carbonic oxide, methane and ethylene.

Among the products of distillation, caoutchene and eupione are the most effective solvents. In the former rubber swells up very much and a considerable quantity of it is dissolved by boiling, the solubility increasing in proportion to the percentage of eupione contained in the solvent.

If oil of caoutchouc is to be prepared for use as a solvent, the receiver in which the products of distillation are collected must be thoroughly cooled so as to retain the very volatile eupione in the distillate, and, of course, the bottles in which the oil of caoutchouc is kept must be hermetically closed.

Commercial Rubber.

The varieties of crude rubber occurring in commerce may, according to their origin, be arranged in three principal classes as follows:

I. American rubber { South American rubber. Central American rubber.

II. African rubber { East African rubber. West African rubber.

III. Asiatic rubber.

IV. Australian rubber.

In commerce these varieties are not always known by regular names. the separate kinds being sometimes called after the province of their origin, though sometimes other regions yield the same kind of pro-

ducts, and sometimes after the shipping place or the city which is the center of trade for the respective variety. A brief summary of the best known varieties, including their commercial names, place of origin, form in which they are brought into commerce, appearance, properties, etc., is given below:

I. AMERICAN RUBBER. 1. SOUTH AMERICA: *Fine Para; Seringa fina,* called by the natives *Borracha* or *Jebe. Origin:* Amazon river, Brazil. *Form:* Biscuits or loaves; weight of the pieces from the Lower Amazon, 6½ to 11 lbs.; from the Upper Amazon, 22 to 33 lbs. *Appearance:* Dark brown to blackish. *Cut surface:* Darker towards the outside, whitish towards the inside. The separate layers can be recognized as leaves or skins. *Odor:* Like smoked bacon. *Adulteration:* Few foreign substances; sometimes mixed with the latex of *Minusops elata, Marcandaruba.* Moisture varies according to the time of gathering. *Loss in working:* 10 to 15 per cent. Strong and elastic. The biscuits frequently bear the name of the factory.

Entrefine Para; ½ fine Entrefine; Grossa. Origin: Amazon river. *Form:* Biscuits or loaves, those from the Lower Amazon weighing from 6½ to 11 lbs. each, and those from the Upper Amazon 22 to 33 lbs. each. *Appearance:* Dark brown to blackish. *Cut surface:* Very different from fine Para, the non-fumigated portions being dirty white, the fumigated ones brown amber color. *Odor:* Less pronounced than that of fine Para, it having an odor of methylamine. *Adulteration:* Few foreign substances, con-

sisting generally of bark. Moisture like fine Para. *Loss in working:* 15 to 20 per cent. Less strong than fine Para. The large loaves and biscuits of fine Para are cut up partly in the trading places and partly in Para, and all pieces not thoroughly fumigated, and containing streaks of non-fumigated rubber, are sorted out as entrefine.

Nigger heads; Para Sernamby; Sernamby de Borracha; Sernamby de Jebe; Cabeça de négro. Origin: Amazon river. *Form:* Comes into market either in large blocks or mostly in irregular pieces, the size of the hand, which, in consequence of solid packing, stick together. *Appearance:* Black. *Cut surface:* Yellowish white with black veins. *Odor:* Smells like methylamine; sometimes mouldy. *Adulteration:* With sand and non-elastic, so-called dead rubber. Very moist. *Loss in working:* 20 to 40 per cent. Lacks resistant power.

Virgin sheets or *Matto-grosso Para* (*Para blanc*). *Origin:* Province Matto Grosso, Brazil. *Form:* Large loaves of regular shape, about two feet long, one foot wide and six inches thick; smaller loaves of half the size. *Appearance:* Pale brown. *Cut surface:* Straw yellow, with greenish marbling, especially on the edges. *Loss in working:* 15 to 30 per cent. Less strong than brown Para. Like Para, it is classed: Fine, ½ fine, Sernamby.

Ceara scraps. Origin: Province Ceara, Brazil. *Form:* Small strips or tears rolled in a lump. In consequence of being solidly packed in a fresh state, the balls stick together and form blocks weighing

up to 330 lbs. *Appearance:* Pale and dark brown amber color. *Cut surface:* Pale amber color; when extended, white and opaque. *Odor:* Very disagreeable, becoming more so by exposure to moist heat. *Adulteration:* Always mixed with vegetable matter, frequently also with sand. Up to 15 per cent. of moisture. *Loss in working:* 20 to 25 per cent.; with inferior qualities mixed with sand, up to 50 per cent. Quite strong. The serum of Ceara rubber can be quite well removed by mechanical pressure.

Pernambuco (Mongabeira). Origin: Province of Pernambuco, Brazil. *Form:* Rectangular patches varying in size; sometimes 5 feet long, 2 feet wide and a few inches thick. *Appearance:* Reddish orange-yellow with saline efflorescence. *Cut surface:* White to rose color. Numerous holes filled with serum containing alum. *Loss in working:* 40 to 60 per cent. Has but little elasticity; flabby; in little demand and sometimes is used only on account of its beautiful color. In time it becomes hard and brittle.

Maranham. Origin: Province Maranham, Brazil. *Appearance:* Smooth, lustrous, no saline efflorescence. *Cut surface:* White to rose color; acquires, on exposure to the air, a beautiful dark wine-red color. *Loss in working:* 25 to 30 per cent. Stronger and more elastic than Pernambuco. The serum contains sugar.

Bahia. Origin: Province Bahia, Brazil. *Form:* Irregular masses or large patches weighing up to

110 lbs. *Appearance:* Reddish-orange. *Cut surface:* White to rose-color, holes with serum and frequently with non-coagulated latex. *Adulteration:* Wood, vegetables, sand, clay. Very moist. *Loss in working:* 50 per cent. Of inferior quality; in little demand.

Carthagena (*Esquebo*). *Origin:* Columbia. *Form:* Large balls weighing up to 190 lbs., formed of patches or strips which are folded together like Nicaragua scraps. *Appearance:* Black. *Cut surface:* Brownish, black, greenish, gray. *Odor:* Of methylamine and mould. *Adulteration:* Earth. *Loss in working:* 25 to 60 per cent. It is quite in demand. The good quality is elastic, but that adulterated with earth is very dead.

Cuidad-Bolivar, Columbia Virgen. *Origin:* Venezuela. *Form:* Like Para rubber. *Appearance:* Like Para. *Cut surface:* Like Para. *Odor:* Slightly fumigated. *Adulterations:* Often mixed with the sap of *Massaranda* and *Pindar.* *Loss in working:* 15 to 20 per cent., according to quality. Resembles Para rubber and is often sold as such.

Cayenne. *Origin:* French Guiana. *Form, appearance and cut surface:* Like Para rubber. *Odor:* Slightly smoky. *Adulteration:* Quite pure. *Loss in working:* 15 to 20 per cent. Value equal to Para.

Peru in slabs, also called *caucho.* *Origin:* Peru. *Form:* Large blocks, or like fine Para. *Appearance:* Deep black, surface granular. *Cut surface:* Yellow; becomes in time slate-color; very porous. *Adul-*

teration: Much sand and water. *Loss in working:* 25 to 30 per cent. Very elastic and highly valued, though the color is not liked. By boiling in water the rubber loses its black color and becomes dirty-white.

Peruvian balls, Sernamby de Pérou, Sernamby de Caucho. Origin: Peru. *Form:* Like niggerheads. *Appearance:* Deep black; surface granular. *Cut surface:* Yellow; becomes in time slate-color; very porous. *Loss in working:* 25 to 30 per cent. Sernambillo (waste) is better than niggerheads, as it contains less water and is less porous.

Guayaquil (in patches). *Origin:* Ecuador. *Form:* Large patches up to 3 feet 3 inches in length, 2¼ feet wide, and about ¾ inch thick. *Appearance:* Blackish. *Cut surface:* Black-green, very moist, with many water bubbles. *Adulteration:* Very impure; earth and vegetable matter; much water. *Loss in working:* 20 to 35 per cent. Partly very elastic, and partly adulterated with earth, and dead like Carthagena rubber.

2. CENTRAL AMERICA. *Colon and Panama. Origin:* Ecuador, Columbia. *Form:* Strips about 4 inches in diameter and up to 10 feet in length. Quality similar to Carthagena rubber.

Mexican and other Central America and West Indies sheets. Origin: Vera Cruz, Taumapilas, Tabasco, Guerero, Baraca, Repic Chiopas. *Form:* Sheets from 0.39 to 1.57 inches thick, and 2 x 2½ inches in length and width; sometimes balls (marbles) 2 to 2½ inches in diameter. *Appearance:* Black. *Cut*

surface: Black, brown, yellow-greenish. In cutting a sheet a brownish liquor sometimes runs out. *Adulteration:* Sand, earth, leaves, sometimes splinters of wood. *Loss in working:* 12 to 15 per cent. Extraordinarily strong.

Guatemala. Origin: Guatemala. *Form:* Sheets. *Appearance:* Black. *Cut surface:* Black, partly yellow-greenish, partly brown; contains a thick fluid (non-coagulated rubber). *Odor:* Very characteristic. *Adulteration:* Dirt, bark, earth. *Loss in working:* 25 to 45 per cent. Partly strong like Guayaquil, partly softer.

Nicaragua, Mexican, Ecuador and West Indian scraps. Origin: Nicaragua, Mexico, San Salvador, Ecuador. *Form:* Either sausages as thick as an arm or balls of at least the size of a head. Sometimes also cubes 2 to 2½ feet long. The scraps are always composed of folded or rolled strips, waste of sheets and spontaneously dried drops. *Appearance:* Blackish. *Cut surface:* Usually blackish and lustrous; sometimes yellowish, but soon turns black on exposure to the air. *Adulteration:* Slight moisture, some cork, sometimes sand. *Loss in working:* 10 to 15 per cent. Very much in demand; classes next to fine Para.

II. African Rubber. *Senegal and Bissao balls. Origin:* Senegambia, Soudan, Bissagos Islands. *Form:* Partly balls, partly sheets. *Appearance:* Black, brown. *Cut surface:* Rose color, white. *Adulteration:* Much moisture, sand, bark, dirt. *Loss in working:* 25 to 50 per cent. Partly very strong, and quite in demand.

Gambia balls. *Origin:* Senegambia, Bathurst, Bissagos Islands, Soudan. *Form:* Balls. *Appearance:* Brownish, white, and black. *Cut surface:* White with a slight tinge of rose-color. *Adulteration:* Moisture, sand, small quantity of bark. *Loss in working:* 20 to 50 per cent. Pure, dry balls are in good demand; second quality is not much liked.

Casamanza (*Boalam*). *Origin:* High table-land on the right-hand bank of the Casamanza river, Senegambia. *Form:* Like Senegal rubber. *Appearance:* Dark brown. *Cut surface:* Grey shading into cream-yellow and reddish; holes with much sand. *Odor:* Bad. *Adulteration:* Much earth and sand. *Loss in working:* 40 per cent. Not much in demand. Is chiefly brought into commerce in March.

Casamanza (*Gambia*). *Origin:* Left-hand bank of the Casamanza river. *Form:* Balls weighing 10 to 28 ozs., and even up to 4 lbs. *Appearance:* At first white, afterwards red-brown. *Cut surface:* Concentric layers; color, red-brown to white; white predominates, but on exposure to the air, it gradually acquires the red-brown tone of the surface. Sometimes concentric veins, black, white and rose-color. The rubber prepared by chemical disintegration, by the addition of vegetable matter, is of a pale amber color. *Adulteration:* Small quantity of foreign substances; quite moist. *Loss in working:* 20 to 40 per cent., according to quality. Quite strong. This rubber would be excellent, if it were not mixed with other varieties of latex, the black rubber contained therein being very sticky, and having an injurious effect upon the paler rubber.

Sierra Leone Niggers, Massai Niggers. *Form:* Balls. *Appearance:* Red, red-brown, white. *Cut surface:* Red and glassy brown, white. *Odor:* None. *Adulteration:* Partly very pure, partly mixed with bark and earth; partly dry, partly moist. *Loss in working:* 10 to 35 per cent. Red, dry balls are highly valued; soft and moist ones are not liked.

Sierra Leone twist: *Appearance:* Brown. *Cut surface:* White. *Adulteration:* Partly very pure, though frequently adulterated in the interior with earth and bark and only covered with good strips. *Loss in working:* 18 to 35 per cent. Strong and highly valued.

Liberia. *Origin:* Liberia. *Form:* Balls and lumps. *Appearance:* White, brown, black. *Cut surface:* Of the balls, white and rose color; of the lumps, green, yellow and white. *Odor:* Of the balls, slight; of the lumps, very bad. *Adulteration:* The balls are pure, but quite moist; the lumps very moist. *Loss in working:* 20 to 40 per cent.

Grand Bassam. *Origin:* Ivory Coast. *Form:* Lumps. *Appearance:* Black. *Cut surface:* Dark green, partly pale. *Odor:* Bad. *Adulteration:* Quite pure, but moist. *Loss in working:* 20 to 30 per cent. Much in demand.

Accrah. *Origin:* Gold Coast. *Appearance:* Brown, black. *Cut surface:* Yellow, brown. *Odor:* Very bad. *Adulteration:* Moist; sometimes mixed with earth. *Loss in working:* 30 to 45 per cent. A good quality of this rubber is much in demand on account of its purity, but the soft article is not

liked. Accrah biscuits pressed on the coast are no longer found in commerce.

Niger Niggers. Origin: Niger Territory. *Form:* Compressed balls. *Appearance:* White, red. *Cut surface:* White; root-rubber, partly red. *Odor:* Slight. *Adulteration:* Partly pure, but moist; the root-rubber contains much bark. *Loss in working:* 20 to 45 per cent. The white balls are strong, and in demand; the root-rubber is resinous and soft.

Gaboon Balls. Origin: French Congo. *Form:* Large and small balls. *Appearance:* Black and gray. *Cut surface:* Of the large balls, rose-color, blue and red; of the small ones, grey, white and green. *Odor:* Bad. *Adulteration:* Bark, sand, very moist. *Loss in working:* 27 to 40 per cent. The large balls are strong and highly valued, but the small ones are soft and in little demand.

Gaboon Tongues. Form: Small, oblong balls. *Cut surface:* White and gray. *Adulteration:* Sandy on the outside, moist, partly calcareous. *Loss in working:* 35 to 45 per cent. In little demand.

Kassaï rouge. Origin: Congo State. *Form:* Small balls, ten of them being stuck together so as to form a short pig-tail. *Appearance:* Red. *Adulteration:* Very few impurities. *Loss in working:* 6 to 8 per cent. Very sinewy. Is considered the best quality of the Congo varieties.

Kassaï noir. Origin: Congo State. *Form:* Pig-tails. *Appearance:* Black. *Adulteration:* Frequently mineral and volatile substances. Of less value than Kassaï rouge.

Kassaï noir in balls. Origin: Congo State. *Form:* Pieces of irregular size stuck together to form balls. *Appearance:* Black. *Adulteration:* Neither sand nor wood, but considerable quantities of volatile, fermenting substances.

Kassaï strips. Origin: Congo State. *Form:* Balls stuck together. *Adulteration:* Volatile, fermenting substances. Quite strong.

Upper Congo (common). Origin: Congo State. *Form:* Balls stuck together. *Adulteration:* Bark and about 8 per cent. water. *Loss in working:* About 15 per cent. Strong. This is the variety first imported from Congo.

Upper Congo (white). Origin: Congo State. *Form:* Balls. *Cut surface:* White. *Adulteration:* Very pure, 6 to 8 per cent. water. Very strong.

Equator. Origin: Congo State. *Form:* Balls stuck together. *Adulteration:* But few impurities, 5 to 7 per cent. water. Strong, good quality.

Lopari. Origin: Congo State. *Form:* Balls. *Adulteration:* Volatile and fermenting substances. Very elastic; as much in demand as Equator.

Busira. Origin: Congo State. *Form:* Balls. Highly valued, almost as much as Equator.

Aruwimi, Mongala, Bumba. Origin: Congo State. *Form:* Balls weighing up to 11 lbs. *Odor:* Very bad and penetrating. *Adulteration:* Up to 35 per cent. of fermenting substances. *Loss in working:* Large. Quality, good.

Uelle. Origin: Congo State. *Form:* Sheets weighing up to 22 lbs. *Appearance:* White. *Adul-*

teration: Quite pure; volatile, but only exceptionally fermenting, substances.

Longer Congo (*thimbles*). *Origin:* Congo State, Angola. *Form:* Square cut pieces. *Appearance:* Quality I., red and black; Quality II., black and reddish. *Cut surface:* Quality I., red and black; Quality II., red. *Adulteration:* Quality I., pure, sometimes sandy; Quality II., contains bark, and in some instances earth. *Loss in working:* I., 12 to 20 per cent; II., 27 to 45 per cent. Quality I., strong though partly resinous; II., when dry much in demand, but not liked when wet.

Luvituku. *Origin:* Lower Congo. *Form:* Balls. Composition and quality like Congo thimbles.

Loanda thimbles. *Origin:* Angola. *Form:* Thimbles or cubes, 0.19 to 1.18 inches in size. *Appearance:* Slate-gray. *Cut surface:* Lustrous, slate-gray with white dots. *Odor:* Offensive, like dry Congo rubber. *Adulteration:* No foreign substances, though recently attempts at adulteration have been made. *Loss in working:* 15 to 20 per cent. Inclines to become soft and smeary, and should be kept in a cold room.

Loanda Niggers. *Origin:* Angola (Loanda). *Form:* Balls strung together in chains. *Appearance:* Quality I., red and black; II., reddish. *Cut surface:* I., red and black; II., red. *Odor:* Slight. *Adulteration:* Quality I., pure and dry; II., much bark, and in some cases sand. *Loss in working:* I., 8 to 15 per cent., II., 20 to 27 per cent. Quality I. is strong and much in demand: Quality II., less

strong, but quite in demand when dry and not oxidized; resinous.

Angola Niggers or Nigger-heads. Origin: Angola. *Form:* Balls of irregular form, 1.18 to 2 inches in diameter. *Appearance:* Reddish-brown. *Cut surface:* Reddish-brown, almost transparent towards the centre; very soft, but becomes hard when exposed for a few days to the air. *Adulteration:* Quite moist; small quantity of portions of plants. *Loss in working:* 20 per cent. Less strong than Loanda Niggers; quite sticky.

Benguela Niggers. Origin: Angola (Benguela and Mossamedes). *Form:* Balls strung together to chains; also small sausages. *Appearance:* Reddish. *Cut surface:* Red. *Adulteration:* Much bark. *Loss in working:* 20 to 25 per cent. When dry the rubber is much sought after, but the fresh article, pale inside, which readily oxidizes, is not in demand.

Mozambique Marbles. Origin: Mozambique. *Form:* Small balls pressed together. *Appearance:* Black and reddish. *Cut surface:* Red, in isolated cases, white. *Adulteration:* Much bark; partly sand; moist. *Loss in working:* 30 to 40 per cent. Soft, of inferior quality; root-rubber.

Mozambique Balls. Origin: Mozambique, German East Africa. *Form:* Smaller and larger balls. *Appearance:* Brown and rose-color. *Cut surface:* Red, brown, rose-color, white. *Odor:* None. *Adulteration:* Quality I[a] I[a] is very pure and dry; inferior quality contains sand and portions of plants, and is moist. *Loss in Working:* 8 to 35 per cent. The

best glassy balls which are cut piece by piece in their place of origin are much in demand on account of their excellent quality and small loss in working. Inferior qualities are also in demand.

Mozambique Spindles. Origin: Mozambique. *Form:* Spindles. *Appearance:* Brown and red. *Cut surface:* Red and brownish; in isolated cases, black. *Odor:* None. *Adulteration:* Bark and sand. *Loss in Working:* 12 to 27 per cent. When unadulterated much in demand, as the rubber is very strong and the loss in working small.

Madagascar, black. Origin: Madagascar. *Form:* Large round pieces. *Appearance:* Black. *Cut surface:* White, rose-color, yellow, green. *Odor:* Offensive. *Adulteration:* Earth, portions of plants, very moist. *Loss in working:* 30 to 45 per cent. Suitable for the manufacture of hard rubber.

Madagascar, pinky. Appearance: Brown and black. *Cut surface:* Rose-color, white. *Adulteration:* Pure, but moist. *Loss in working:* 25 to 40 per cent. Highly valued. Not very strong, but elastic.

Madagascar Niggers. Form: Large balls. *Appearance:* Black and yellow. *Cut surface:* Brownish, white, black and yellow. *Odor:* Slight. *Adulteration:* Dry, but generally much adulterated with earth. *Loss in working:* 20 to 60 per cent. The yellow West Coast Niggers are frequently very soft, but sometimes, like the East Coast Niggers, are very strong, and are then highly valued.

III. Asiatic Rubber. *Assam. Origin:* North

West Bengal (Brahmapootra). *Form:* Lumps weighing up to 5½ ozs. which adhere firmly to the cover as this rubber becomes rapidly viscous and smeary. *Appearance:* Brown. *Cut surface:* Dark, sometimes gray, sometimes reddish with white nearly transparent patches. *Adulteration:* Moist sand, wood, earth. *Loss in working:* 25 to 40 per cent. Was formerly much liked, but is now less highly valued because it has deterioarated in quality. It is disappearing from the market.

Rangoon. *Origin:* Burma, Cochin-China, Anam, Tonkin. *Form:* Irregular masses. *Appearance:* Very dark brown. *Cut surface:* Lustrous, white, red and black marbled. *Adulteration:* Always contains wood. *Loss in working:* 20 per cent. Less valued than the preceding variety.

Penang. *Origin:* Sumatra and other Sunda islands. *Form:* Large bisected lumps and balls. *Appearance:* Red, brown. *Cut surface:* Red, rose-color, whitish. *Adulteration:* Wood, small quantity of earth, partly moist. *Loss in working:* 15 to 30 per cent. A good dry quality is highly valued; the moist, sticky article is not in demand.

Ceylon. *Origin:* Ceylon. *Form:* Irregular cubes about 4 inches large. *Appearance:* Black. *Cut surface:* Dark brown, pale brown, and transparent. *Adulteration:* Sand, earth. *Loss in working:* 20 to 25 per cent. Quite strong.

Java and Padong. *Origin:* Java, Sumatra, and other Sunda islands. *Form:* Large bisected lumps and balls. *Appearance:* Red, brown. *Cut surface:*

Red, glassy, rose-color, white. *Odor:* Slight. *Adulteration:* Wood, small quantity of earth, partly moist. *Loss in working:* 12 to 30 per cent. Good, dry ware is much in demand; the moist, sticky article is not valued.

Borneo. Origin: Borneo. *Form:* Large lumps, flat pieces, and balls. *Appearance:* Black. *Cut surface:* White, rose-color, blue, green. *Adulteration:* Earth, wood, portions of plants; very moist. *Loss in working:* Quality I., 35 to 45 per cent.; II., 35 to 50 per cent.; III., 40 to 60 per cent. Quality I., very strong and beautiful; II., partly soft; III., frequently contains dead pieces.

Borneo Djambès. Origin: Sumatra. *Form:* Balls and sheets. *Appearances:* Brown-red. *Cut surface:* Greenish-red. *Adulteration:* Alumina, much water. *Loss in working:* 45 per cent. and over. But little in demand on account of the impurities.

Borneo (Ben Koclen). Form: Thin sheets. *Appearance:* Brown. *Cut surface:* Inside white. *Adulteration:* Quite pure. Good quality.

IV. Australian Rubber. *New Caledonia. Origin:* New Caledonia. *Form:* Biscuits like Para rubber weighing 13 to 22 pounds; also balls. *Appearance:* Pale and brown, sometimes a black tinge. *Cut surface:* White veined. *Odor:* Smoky. *Adulteration:* Very pure. *Loss in working:* 12 to 20 per cent. A very good quality, when not mixed with other varieties. Somewhat resinous. Has been but recently introduced in the European market.

Statistics. As regards the statistics of the rubber

trade, there is the broad fact that the world's requirement in raw rubber is fast rising from 120 to 130 million pounds a year, in confirmation of which we give an estimate of the world's production and consumption of rubber, supported by such detailed figures as are available.

Production.	*Cwt.*	*Consumption.*	*Cwt.*
Brazil, Peru, etc. (Para). . . .	450,000	America (United States and Canada)	400,000
Brazil, Ceara, etc.	94,000	United Kingdom and Dependencies save Canada .	450,000
Brazil, Mangabeira	65,000	Continent of Europe.	400,000
Guiana	6,000		
Bolivia	30,000		
Rest of South America	40,000		
Central America and Mexico .	50,000		
Java, Borneo and Eastern Archipelago	20,000		
East and West Africa	480,000		
Madagascar and Mauritius . .	10,000		
India and Burma	8,000		
Ceylon	150		
Australia	——		
Cwt.	1,250,150	Cwt.	1,250,000

The principal market for crude rubber in Europe is Liverpool, which of all kinds of rubber

In	Imported, Tons.	Sold, Tons.	Remained in stock, Tons.	In	Imported, Tons.	Sold, Tons.	Remained in stock, Tons.
1887	7330	5890	1440	1893	11330	9830	1500
1888	7900	6485	1415	1894	11560	16285	1275
1889	8750	7760	990	1895	13720	12640	1080
1890	9900	8610	1290	1896	17300	15640	1660
1891	10680	9480	1200	1897	15365	14285	1086
1892	10400	8950	1450				

London, Hamburg, Rotterdam, Antwerp, Bordeaux and Marseilles also import rubber.

The importance of the London market compared with that of Liverpool is shown in the annexed table:

In	Imported, Tons.	Sold, Tons.	Remained in stock, Tons.	In	Imported, Tons.	Sold, Tons.	Remained in stock, Tons.
1887	2400	1385	1015	1893	1720	1280	440
1888	2280	1313	977	1894	1935	1485	450
1889	1660	1050	610	1895	1720	1260	460
1890	1893	1247	646	1896	1579	1235	1137
1891	1900	1310	590	1897	460	344	320
1892	1740	1255	485				

The principal European countries together with the United States imported rubber in 1896–7 to the following approximate amount and value:

COUNTRIES.	Years.	Quantity. Tons.	Value. £.
Great Britain	1896	21,558	4,991,122
France.	1896	5,177	1,111,256
Germany	1897	8,436	2,320,150
Belgium	1897	2,236	545,835
Holland	1897	1,672	141,667
Austria-Hungary . . .	1897	2,109	811,415
United States	1897	18,821	4,514,587
		60,009	14,436,032

Prices of India Rubber.

(From S. Figgis & Co.'s Fortnightly Price Current, June 15, 1899.)

		s. d.		s. d.
India rubber	Red hard clean ball	3 2	to	3 6
East African Ports, Zanzibar and Mozambique Coast	White softish ball	2 8	to	3 0
	Unripe root	1 2	to	2 1
	Liver and Lamu ball	2 8	to	3 0
	Sausage ordinary to fine	3 0	to	3 4½
	Sausage without sticks	3 3	to	3 6
India rubber, Assam	Good to fine	2 8	to	3 3
	Common foul and middling	1 10	to	2 5
Rangoon	Fair to good clean	2 11	to	3 1
Madagascar Tamatave, Majunga and Nossibe.	Good to fine pinky and white	3 2	to	3 4½
	Fair to good black	1 8	to	2 6
India rubber, Borneo	Fair to fine nigger ball	1 5	to	2 7
	Fair to fine clean	1 9	to	2 5
Java, Singapore and Penang	Mixed, part dead	1 1	to	1 6½
	Good to fine red selected	2 8	to	3 1
	Mixed, part soft	1 7	to	1 10½
	Pickings, part common	0 9	to	1 3

CHAPTER II.

MECHANICAL TREATMENT OF CRUDE RUBBER.

Rubber in the crude state finds but little application, and besides the pieces used for erasing pencil marks, which are simply cut with a knife from Para biscuits, it is occasionally employed for billiard cushions, and in the form of square non-vulcanized threads. All other articles serving for thousands of diverse purposes, require more or less manipulation.

In the industrial working of rubber, the first matter to be attended to is the removal of the various impurities present in the crude material. These, as previously mentioned, are in some cases natural products, which have originated with the rubber, while in other cases they owe their presence to careless collection or to adulteration. The admixtures may range from fragments of bark or wood to stones or large lumps of clay, such as are sometimes introduced into niggerhead rubber, hay or a similar substance being also placed inside to make the mass about equal in specific gravity to the genuine article. Alum and sulphuric acid are often employed to effect the coagulation of the milky juice, and traces of them remaining in the rubber appear, in some instances, to work mischief.

The operation of purifying the crude rubber consists in softening and superficial washing, cutting up, rolling or actual washing, and drying.

In manipulating the crude material it is advisable to use only rubber of one and the same variety at one time, as different kinds demanded different treatment.

Generally speaking, American rubber requires less manipulation than the East Indian or African article. Hence if the two kinds mixed in one lot were to be worked, the first would be purified while the other would require still further treatment.

Softening or superficial washing. The rubber as brought from the store-room is too solid and hard to be worked, and the ordinary temperature of our climate is not sufficient to impart to it the requisite softness. Hence it must be artificially softened, which is the most simple of all the manipulations. The rubber is placed in water heated by steam, in which it remains from 3 to 24 hours, according to requirement. Wooden vats or iron tanks are most suitable for the purpose. For certain varieties it is recommended to add caustic soda to water, but the use of acidulated water should be avoided.

Cutting up. The lumps of the softened crude rubber are then cut into slices by means of a sharp knife, generally by hand, as thus any large stones or other foreign substances can be removed. However, cutting machines are frequently used, the older kinds resembling somewhat a straw cutter. Sharp knife blades were set obliquely on the spokes of a

wheel which revolved rapidly. The lumps of rubber to be cut up were pressed by a lever against the knives, which were kept wet with water. Although such a machine is of quite simple construction and works satisfactorily, it has the disadvantage of requiring frequent repairs. For instance, if the edge of the knife hits a pebble in the rubber, it becomes notched, and then tears rather than cuts, and hence the knives must be frequently ground. To prevent constant interruptions of the work, the knives should be so arranged that they can be readily taken off, and replaced by newly ground knives.

An improvement in cutting machines is shown in

FIG. 1.

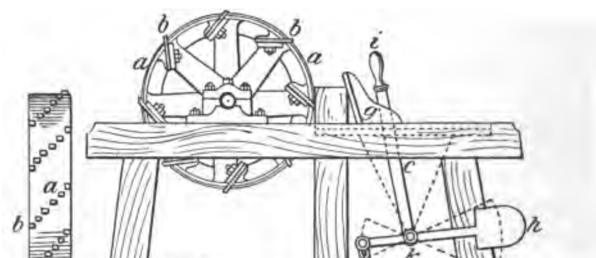


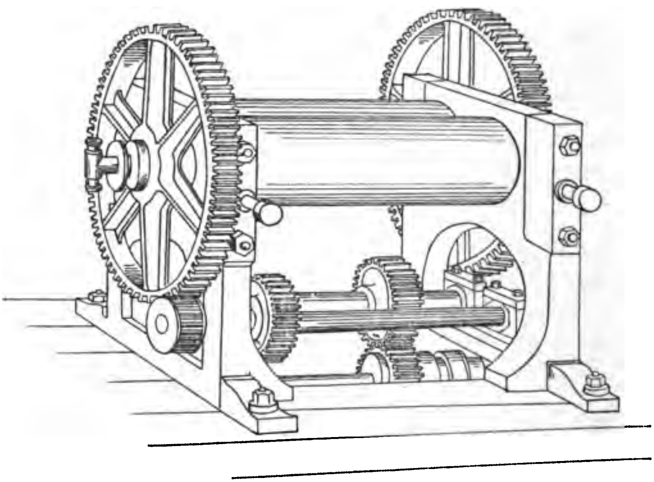
Fig. 1. In consists of an iron drum, *a*, 24 to 28 inches in diameter and 8 inches wide, with a large number of obliquely set knives, *b b*, which project slightly above the periphery, and are arranged in rows, as seen in the illustration. The lump of rubber is pressed against the knives

by a lever arrangement consisting of the lever *d*, upon which the workman stands, and a joint lever, *c*, with its fulcrum at *k*, and the upper blade-shaped end, *g*, presses the rubber against the knives. A counter weight, *h*, brings the lever back, the manipulation of which is facilitated by the handle *i*. The drum, which revolves with great velocity, tears the rubber into small chips. Previous softening of the rubber is not required in working with this machine.

Rolling or washing. This is the most essential part of the operation of purifying rubber, its object being to remove the foreign substances enclosed in the mass. Fig. 2 shows a machine most generally used for the purpose. It consists of two massive cast iron rolls lying horizontally alongside each other, and revolving with unequal velocity towards the inside. The surfaces of the rolls are either corrugated or smooth, but the position of the two rolls is always the same. In English and American factories corrugated rolls are preferred, since the corrugations facilitate purification by penetrating into the rubber and grinding up the foreign substances. As shown in the illustration, the rolls rest in a strong iron frame. The bearings of the back roll rest laterally against the frame, and those of the front roll against two screws. The revolution of the rolls, each by itself, is, as a rule, effected by means of cog-wheels from a principal axis under the floor, though there are also machines in which the revolution is directly transmitted from one roll to

the other. However, the rolls always revolve towards the inside. By means of the screws on the front side of the frame, the rolls can be set closer or further apart. Underneath the rolls is a sheet-iron reservoir covered with a perforated plate. Over the rolls, about 1 to 1½ feet, exactly above their point of contact, is a perforated pipe, through which during

FIG. 2.



the work cold water is constantly discharged, which runs off through a pipe in the sheet-iron reservoir mentioned above. The rubber to be washed is fed by the hand in very small quantities, according to the size of the machine, between the revolving rolls, the cock on the water pipe being at the same time opened. The rubber is caught by the rolls, crushed, torn and pulled apart, while the water penetrates

into all the interspaces, washing away the particles of bark, fibres and earthy constituents, and removing also all other crushed foreign substances. After repeatedly passing through the rolls, the product obtained is a long, blotting-paper like sheet with a wrinkled surface, which shows numerous small elevations separated from each other by small cavities, and which gives a characteristic appearance to rubber in this state.

Each machine is attended by one workman. The occupation is not without danger, since by the slightest inattention the fingers may get between the rolls, and if the machine is not instantly stopped, the hand and arm will be drawn in. Hence every machine should be provided with a promptly acting disengaging gear. Such an arrangement will be described later on in speaking of masticating rolls.

The size of the machines varies very much. However, as a rule, the rolls are 2 to 2½ feet long, with a diameter of 1⅓ to 1½ feet, and the velocity is 8 to 12 revolutions per minute for one roll, and 3 to 4 for the other.

Some factories use hollow rolls so arranged that they can occasionally be filled with steam, and in this case the machine, as will be explained later on, serves for two operations. For large factories this arrangement, however, is not suitable.

All varieties of rubber cannot be washed with the same facility. Para rubber, containing the least impurities, is washed most quickly. The so-called fat or pitchy varieties yield the foreign substances

with difficulty, and frequently the impurities are so firmly fixed in the mass that they cannot be removed. Naturally very dry varieties of rubber cannot always be rolled into sheets or leaves, as they do not hold together, and in many cases the rubber comes in small pieces from the machine. If washing is thoroughly done, the sheet contains no foreign substances, except water, which is removed by

Drying. For this purpose the rubber is suspended over iron wires or wooden poles either in lofts where it is exposed to the air, or in drying chambers which can be heated to 122° to 140° F. This operation requires no special attention, but it may be said that fat or pitchy varieties require a low temperature for drying, since by drying at a high temperature their natural defects would become still more prominent. The sheets would tear, fall upon the floor and stick together in balls from which the water would evaporate very slowly and with great difficulty. Not very adhesive varieties of rubber which come in small pieces from the washing rolls are dried upon frames.

For drying it is of great importance whether the room is more or less light, or more or less exposed to the air. A good draught facilitates drying extraordinarily, and in summer the operation is finished in a few days. More time is, of course, required in winter, and steam heat, carefully applied, is then of great use. The injurious effect of strong light upon rubber has previously been referred to, and hence the darker the drying room, the better.

When dry the rubber is taken from the wires or frames, folded like cloth or rolled together in packages. It is then brought into a special store room where it is protected from light and moisture and kept until required for further working.

By washing and drying the rubber has lost a portion of its weight, the difference between the gross weight of the crude material and the net weight of the purified dried article constituting *the loss in washing.*

The annexed table shows the loss with some varieties, though it is difficult to give definite figures:

Para	10 to 16 per cent.
Sernamby	15 " 35 "
Mozambique (spindles) . . .	10 " 25 "
" (rose color, balls)	15 " 25 "
Columbia	10 " 25 "
Peru (sheets)	30 " 40 "
Guatemala	20 " 40 "
Assam	10 " 30 "
Java	20 " 35 "
Borneo	10 " 45 "
Guayaquil	30 " 50 "
Senegal-Soudan	20 " 35 "

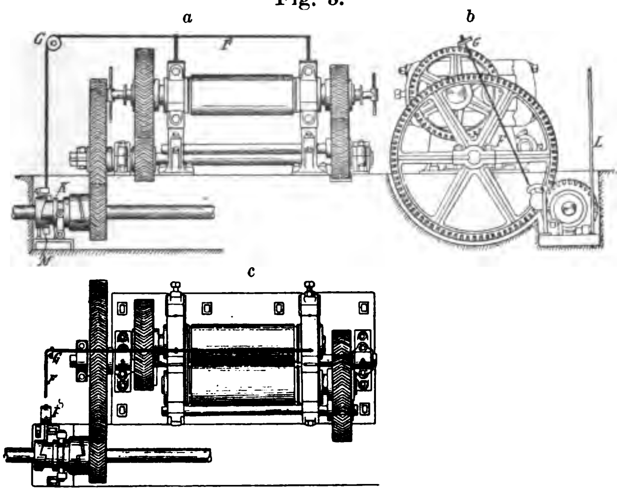
It frequently happens that two shipments of rubber which are sold as the same variety vary very much as regards loss in washing, the difference amounting sometimes to as much as 25 per cent.

Further working of the washed crude rubber. For the purpose of further manipulation, the washed

sheets when dry have again to pass through between rolls, this time, however, without the use of water. The rolls are hollow and heated by steam. According to the purpose intended, they act either exclusively as a masticating machine, or at the same time as a masticating and mixing machine, their construction being, however, the same in either case. The machine consists of two rolls each about 2 to 3 feet long and 16 to 20 inches in diameter, which revolve one towards the other. As a rule they are placed one alongside the other, the arrangement of one above the other being the exception and seldom used at the present time. In all other respects they closely resemble the washing-rolls. The accompanying illustration, Fig. 3, *a*, *b* and *c*, shows mixing rolls from the front, side and above. It also shows the disengaging gear mentioned on page 97. The latter has the advantage that the workman can engage it with one hand by pulling a rope, even if the other hand should have been drawn in between the rolls. Its construction and mode of operation are as follows: The rope *F* is carried tight over the pair of rolls from one standard of the frame to the other, then over a pulley *G* to the latch *I*. The latter is provided with a catch which acts on the lever with the counterweight *K*. If now the instant disengagement of the rolls becomes necessary, the workman pulls the rope *F*. By this pull the latch *I* is drawn upwards, whereby the counterweight *K* is released; *K* falls down and the piece *M*, which is rigidly con-

nected with the lever, makes a turn upwards, slides along on the surface of the screws and disengages the clutch coupling, whereby the disengaging gear is pushed to the left side, and the rolls are brought immediately to a standstill. Reëngaging is effected as follows: The lever which carries the counterweight *K* is lifted by means of the rope fastened to

Fig. 3.



it, the latch is again engaged and the disengaged gear *L* pushed to the right.

While up to this point the treatment of all varieties of crude rubber for further manipulation is the same, from this stage on it varies according to whether pure unmixed mass for the manufacture of fine cut sheets is to be prepared, or a mixed mass which for certain purposes must receive necessary

admixtures. In the first case the rolls, as previously mentioned, serve exclusively as macerating rolls, and in the latter, simultaneously as macerating and mixing rolls.

Fine-cut sheets form an important article of commerce, and for their manufacture only the best quality of Para rubber should be used. The sheets of rubber, without the addition of any foreign substance, are worked in the macerating rolls until a homogenous mass free from air is obtained, which comes from the machine in the form of rolls. The latter are subjected to strong pressure in a hydraulic press, whereby larger and more homogeneous blocks are obtained, which are stored for several months at a varying temperature by which means their texture becomes closer and their quality is improved.

Other methods are in use for obtaining blocks of rubber from the crude and washed materials, which consist in forcing it into moulds without masticating, and consolidating it by placing the moulds, keyed or wedged together with their charge, in a heater at about 240° F. for a few hours. Washed Para yields good sound blocks in this way, but the rubber is deprived of more of its strength than if masticated, and is darker in color.

The blocks are next cut up into sheets of different thicknesses. Square blocks are clamped to a plate, which can be raised to any height, according to the thickness of sheet required. This passes forward to an oscillating knife, which slices up the rubber. The knife can be set in an opposite direction, so as

to make another cut as it passes back again, and so on. Cylindrical blocks are forced upon a stout spindle, which rotates in front of a similar, though much longer knife. The thickness of sheet is regulated by the feed-wheels, which are changed as required, and when the machine is once started, a block can be cut without further attention unless demanded by a defect in the machine itself, which occurs generally in the friction arrangement which works the feeding gear. The machines are worked at very high speeds, and a good supply of water is kept continually flowing over the knives. The sheets are generally hung up to dry and season, and are soaped, and laid carefully one on the other, or rolled up for storage. The cutting up must be done in a cool room, for if the rubber gets soft, it must be again placed in a cold place to harden. Soft spots or patches will lead to inequalities in the thickness.

The most usual commercial thicknesses in which these plates are manufactured are measured according to the following scale for the numbers:

Nos.	1	2	3	4	5	6	7	
	4.15	3.26	2.58	2.35	1.85	1.66	1.40	millimeters.
Nos.	8	9	10	11	12	13	14	
	1.14	0.96	0.83	0.62	0.54	0.46	0.41	millimeters.
Nos.	15	16	17	18				
	0.37	0.33	0.20	0.18	millimeters.			

The manufacture of fine cut sheet was invented by Charles Macintosh, and was for a long time protected by patent, which was owned by Charles

Macintosh and Co. They are, however, now manufactured by several English firms and also in Fance and in Germany. They are frequently colored brown, red or green by the admixture of pigment, but green sheets have now almost entirely disappeared, black and brown being preferred, as they are better in quality.

Up to within a few years adulteration of fine cut sheet was entirely unknown, but at present sheets are brought into commerce, which for the purpose of reducing the price, and frequently also with the object of defrauding, contain up to one-third of cheaper substitutes.

In a similar manner as fine cut sheets, square threads may be cut from the pressed blocks. These threads were formerly frequently used in this crude non-vulcanized state, but at present they are seldom employed, since non-vulcanized rubber becomes hard at 32° F., and soft and sticky at over 86° F.

If, on the other hand, mixed mass is to be prepared from the washed crude rubber, the latter must first be softened by passing it through the heated macerating rolls to soften it for the reception of the admixtures. Mixing is, as a rule, effected in the same machine, which then serves as macerating and mixing rolls. A Frenchman has humorously designated the manufacture of rubber as "the art of mixing rubber with cheap substances without impairing too much its special properties." In order to be right, he might have added, "and to make its application more suitable for various pur-

poses or to cheapen it." In fact in no other industry is there a material which is so receptive to these manipulations, and to which it is possible to impart so many varying qualities. The admixtures consist of sulphur in sufficient quantity for vulcanization, and of other substances conditional either on the future use for which the material is intended or for the production of an exactly determined degree of hardness, tenacity, as well as of color, or finally for the purpose of cheapening the product. The principal ingredients used are, litharge, zinc-white, chalk, heavy spar, metal, asbestos, ground hemp and a few other substances such as glass dust, fine sand, etc., which, however, are less frequently employed. Besides zinc-white, already mentioned, the following materials are used for coloring: Cinnabar, antimony pentasulphide, ferric oxide, ochre, ivory black and lamp black. The receipts for these mixtures upon which besides the choice and use of the right variety of crude rubber, the production of the innumerable various qualities of vulcanized rubber depends, are jealously guarded in the various factories as trade secrets. For an exact repetition of a certain composition, an actual knowledge of the ingredients used is absolutely necessary, since a chemical analysis does not furnish sufficient guiding points for reasons which will be explained later on, and even practical experiments give only an approximately favorable result after long futile groping.

The manipulation of kneading and mixing is very

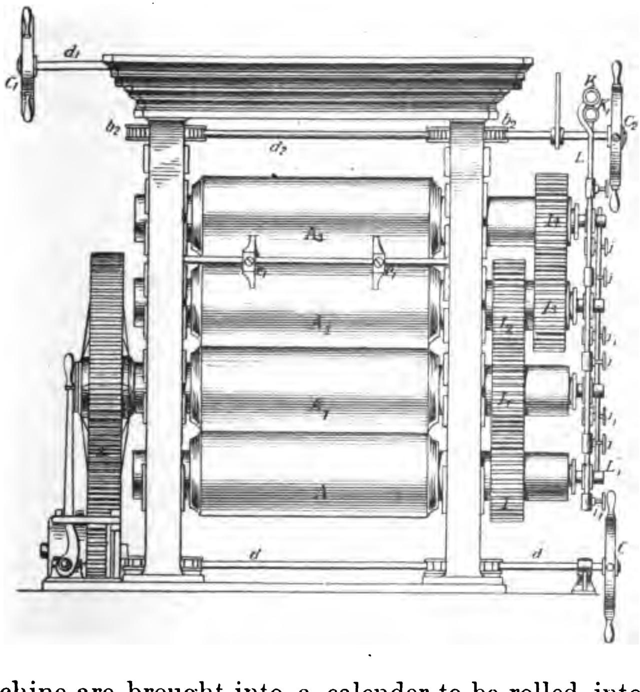
simple, and is readily understood from the construction of the machine and the nature of the material to be worked. The quantities of washed crude rubber, which, of course, must not be of the same kind, but of different varieties, which are required for the intended quality of the mass, and the substances to be added, are carefully weighed and then introduced together in small portions between the rolls. The larger part of the material combines at once to a plastic mass, which either adheres by itself to the front roll and is carried along by it, or if such is not the case, is taken up by the hand of the workman and lifted up. In this manner a loose mantle is rapidly formed upon the front roll, which glides through between the rolls as long as the machine is in operation. The material not taken up by the roll, or crumbs which become detached and fall upon the sheet underneath the rolls, are carefully gathered up and fed from above the rolls. The mass having several times passed through between the rolls, the mantle is cut open crosswise with a short sharp knife, made into a roll, and the latter, head foremost, is again passed through between the rolls. This operation is repeated until uniform maceration and mixing have been effected. The mass in the form of a roll is then taken from the machine in the manner just described.

In another form of machine, the rolls revolve in an iron box, the object of this being to prevent crumbs from falling down, and to save the attendance of a workman. Theoretically, this construc-

tion is correct, and it will be referred to later under gutta percha, in the manipulation of which it is used, but in the rubber industry it has been found to be of no practical value.

The rolis of rubber taken from the mixing ma-

FIG. 4.



chine are brought into a calender to be rolled into sheets. Fig. 4 represents a calender with four rolls. A, A_1, A_2, A_3 are four chilled iron rolls cast hollow, so as to admit steam or water. A and A_3 (Fig. 4) can be moved nearer to or further from A_1, and A

by screw-gearing worked by a wheel C and C_2. The temperature of the rolls exerting great influence upon the uniformity of the sheets as well as upon the avoidance of stripes, so-called flowers, and especially of air bubbles, provision is made for the admission of cold water by a pipe on the axis of each roll, and in addition there is a pipe for the discharge of steam as well as of water. The sheets as they come from the rolls are caught by a cloth, and, to prevent sticking together, are rolled together with it upon a wooden spindle.

CHAPTER III.

VULCANIZATION.

BEFORE describing this operation a brief reference to some of the characteristic peculiarities of crude non-vulcanized rubber may be of service. As has previously been mentioned, at a temperature of 86° F. it commences to get soft, and at 122° F. becomes very adhesive. But, on the other hand, at a temperature of 50° F. it becomes hard and stiff, and at 32° F. thin plates will break after being repeatedly bent backward and forward. By the action of atmospheric air and light, and especially in the presence of moisture and heat, crude rubber is oxidized and becomes a pitch-like, sticky mass. By the discovery of vulcanization these evils have been removed without impairing the valuable properties of rubber. Vulcanization is effected by combining rubber with sulphur with the assistance of heat.

The celebrated French chemist Anselme Payen has made very interesting experiments in this direction, and ascertained that when a disk of crude rubber is submerged in a bath of melted sulphur, it swells up at 248° F., and absorbs a certain quantity of sulphur. In the course of a quarter of an hour the rubber shows no essential change, it being always sticky when touched. By continuing, how-

ever, the experiment 30 to 40 minutes and raising the temperature to 266° to 284° F., the rubber acquires a yellowish color, it is no longer sticky, its elasticity is considerably increased, and it is no longer changed by the influence of cold. The same effect is produced when rubber previously mixed with flowers of sulphur is exposed for the same length of time to a temperature of 266° to 284° F., and also at every degree of heat between the melting point of sulphur and 320° F., the effect being the quicker the higher the temperature is.

In this experiment are included all the distinctive features of the vulcanizing process. However, vulcanization can be effected not only by pure sulphur, but also by means of different sulphides, with chloride of sulphur, and several other substances, such as iodine, bromine, etc. For industrial purposes, however, only pure sulphur is employed, and for special purposes the so-called cold vulcanization with carbon disulphide and chloride of sulphur.

Cold vulcanization. According to this process, which was invented in 1846 by Parkes, of Birmingham, the rubber is suspended for a shorter or longer time—1½ to 3 minutes, according to thickness of the articles—in a cold mixture of 100 parts of carbon disulphide and 2½ parts of dichloride of sulphur. When taken from the bath the articles are quickly dried in a current of air of 77° F., or, in order to prevent the dichloride of sulphur from acting for too long a time, they are first immersed in lukewarm water and then dried. In place of

carbon disulphide, carefully refined petroleum may be used.

This process of vulcanizing is extensively used for surface-curing, such as single textures for garments and sundry small articles manufactured from masticated sheet rubber, such as tobacco pouches, tubing, rings, etc. For thinner articles it has been recommended to use: Dichloride of sulphur 1 part by weight, carbon disulphide 30 to 40 parts, and to suspend the articles in the bath for 60 to 80 seconds.

For thicker articles the following bath is recommended: Dichloride of sulphur 1 part by weight, carbon disulphide 60 to 80 parts. Allow the articles to remain in the bath for 3, 4, to 5 minutes. Articles of extra thickness must be repeatedly plunged into the fluid until vulcanization is complete, when they are washed and dried.

It is, however, more suitable in all cases to work with a reduced solution of dichloride of sulphur, as it is then possible to stop vulcanization at any moment. If the articles are allowed to remain too long in the solution, over-vulcanization may take place, that is, the surface of the articles becomes hard and brittle.

Small articles, especially such as have sharp outlines produced by stamping, can be perfectly vulcanized by this method and their outlines preserved, which they would lose by any other process. Articles of special beauty should be thoroughly washed when taken from the bath, and then immersed for 50 to 70 minutes in boiling caustic soda

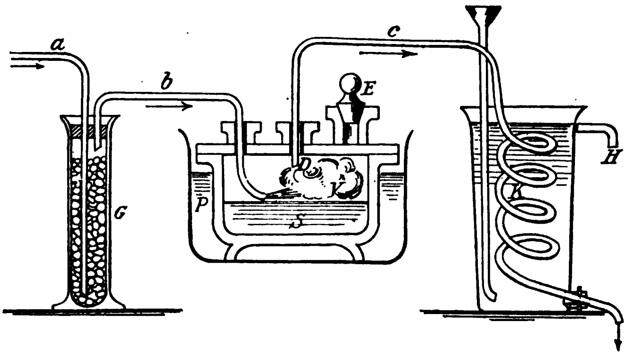
solution of moderate strength. The caustic soda dissolves the free sulphur and the surface of the article will present a uniformly gray color.

It is immaterial whether solutions of dichloride of sulphur in carbon disulphide, or solutions prepared with the aid of anhydrous petroleum are used. For the sake of completeness the preparation of dichloride of sulphur and of anhydrous petroleum will here be given.

Preparation of dichloride of sulphur. Dichloride of sulphur is very easily prepared by passing dry chlorine over dry powdered sulphur. The sulphur should be dried immediately before the operation, and then placed in a tubulated retort provided with a receiver thoroughly cooled. The chlorine passes through a pipe fitted in the tubulure. Perfectly dry chlorine is obtained by passing it through a pipe filled with pumice stone saturated with sulphuric acid. For the success of the operation it is absolutely necessary that both materials should be perfectly dry, since dichloride of sulphur decomposes on coming in contact with water. The action of the two bodies upon each other commences as soon as the retort containing the sulphur is heated. A reddish-yellow fluid, consisting of a solution of free sulphur with dichloride of sulphur collects in the receiver. To free the dichloride from the free sulphur the liquid is distilled until it boils at exactly 266° F. Distillation may, however, be omitted if the presence of free sulphur does not exert a disturbing influence upon the vulcanizing process.

The apparatus shown in Fig. 5, is well adapted for the preparation of dichloride of sulphur. The chlorine passes from the developing vessel through the pipe *a* into the glass cylinder G. The latter is filled with glass balls moistened with sulphuric acid, and entirely dry chlorine passes into the earthenware vessel V, which is provided with an earthenware lid, *D*. The lid is provided with a neck E, which serves for the introduction of the sulphur. The

FIG. 5.



vessel V stands in a sheet-iron vessel filled with paraffin oil P, and is heated so that the sulphur S is heated slightly above its fusing point. The vapors of dichloride of sulphur escaping through C, are condensed in the glass receiver K.

Dichloride of sulphur is a mobile, reddish yellow liquid, having a peculiar, penetrating, disagreeable odor, and fuming strongly in the air. Specific gravity = 1.680. It boils at 276.8° F. Brought in contact with moisture, it decomposes, forming

hydrochloric and sulphurous acids, and causing a deposit of sulphur upon the neck of the bottle.

As dichloride of sulphur severely attacks the mucous membranes of the nose and mouth, as well as the eyes, and produces a convulsive cough and difficulty of breathing, followed, if the air impregnated with its poisonous vapors is inhaled for any length of time, by lung and throat diseases, the greatest precaution should be observed to protect the workmen from its evil effects. It should be kept in bottles with ground-glass stoppers.

Preparation of anhydrous petroleum. For this purpose bring the petroleum into a tank lined with lead and provided with a stirring apparatus. Mix it with the tenth part of its weight of sulphuric acid, and after stirring the mixture for several hours, allow it to rest. The supernatant petroleum is then brought into a still, and to every 100 parts of it add ¼ part of burned lime, finely powdered, to fix the last traces of acid. The petroleum is then distilled off. To prevent the petroleum thus rectified from absorbing moisture from the atmosphere, it should be kept in glass bottles securely stoppered, the balloons used for storing hydrochloric acid being very suitable for the purpose.

Warm vulcanization. According to this method, invented by Hancock, the articles to be vulcanized are brought into a bath of melted sulphur heated to from 284° to 302° F., and allowed to remain in it until they are uniformly permeated and have absorbed about 10 to 15 per cent. of sulphur. How-

ever, before the articles are immersed in the bath, it is advisable to spread them out in a heated room for 24 to 36 hours, so that the seams cemented together with benzine or rubber solution may become thoroughly dry, as otherwise they may burst open. After being taken from the sulphur bath, a solid crust of sulphur is formed, on cooling, upon the outer surface of the articles, which has to be scraped off or rubbed off upon grooved boards. The articles are then placed in a room heated to from 86° to 104° F. Nothwithstanding the rubbing or scraping off of the outer crust of sulphur, the articles vulcanized according to this method contain still an excess of sulphur, which on rubbing or pulling the article, deposits a fine gray powder on the surface. This may be readily remedied by washing in weak soda solution. This method yields good results with articles made of fine cut sheets. When carefully carried out, it is preferable to cold vulcanization.

Gérard's process. Gérard has recommended the use of concentrated solution of liver of sulphur (pentasulphide of potassium) for vulcanizing. The solution is obtained by fusing potassium carbonate together with sulphur. By using a smaller quantity of sulphur, trisulphide of potassium is obtained, with more sulphur than pentasulphide of potassium. For preparing the last-named combination, the following quantities are used:

Carbonate of potassium .	276.8 parts
Powdered sulphur. . .	256.0 parts

However, the figures given above represent pure carbonate of potassium, *i. e.*, 100 per cent. potash, and as the commercial article is never entirely pure, a smaller quantity of sulphur corresponding to the percentage of potash in the carbonate must be used.

The substances are first reduced to a fine powder, then quickly mixed together, as potash absorbs considerable moisture from the atmosphere, and fused in a crucible in quantities of from 45 to 55 lbs. The crucible must be comparatively large, as the mass, in consequence of the escape of carbonic acid, strongly effervesces during fusion. The mass is kept at the fusing point until effervescence ceases, and is then scooped with an iron ladle into shallow sheet-iron moulds and allowed to cool. The congealed mass of pentasulphide of potassium, commonly called liver of sulphur, on account of its brown color, should at once be brought into closely-stoppered glass vessels, as it decomposes when exposed to the air.

For vulcanizing, a concentrated solution (25° B.) of pentalsulphide of potassium is used. The solution is quickly brought to the boiling point in a porcelain vessel. The articles are then immersed in the fluid and allowed to remain until vulcanization is complete.

This process has the advantage of being entirely innocuous, and at the same time inexpensive. However, to become generally available it would seem to require further improvements, as experiments have

shown that only thin pieces of rubber become thoroughly vulcanized, thicker pieces not being uniformly penetrated.

According to another process the rubber is allowed to remain for 3 hours under a pressure of three atmospheres in a solution of pentasulphide of calcium of 25° B., heated to 284° F. When taken from the bath the rubber is washed in water and dried. This method yields excellent results, the rubber being thoroughly and uniformly vulcanized and after washing presents a smooth, soft surface, almost velvety to the touch. However, this method is also only suitable for articles of smaller dimensions. For the purpose of employing it for larger articles, Gérard recommends to mix the rubber with finely powdered earthy substances, calcium hydrates being most suitable. Carefully mix in the mixing rolls rubber 100 parts, sulphur 6, calcium hydrate 6 to 10, and for vulcanizing expose the articles, according to their thickness, for 1½ to 3 hours in a closed vessel to a steam or water bath at 284° F.

Mechanical combination of rubber with sulphur. This process, invented by Goodyear, is the most important and most generally used. It consists essentially in mechanically mixing at the ordinary temperature a certain quantity of rubber with a certain quantity of sulphur, and exposing the mixture under a certain pressure to a certain degree of heat. To the washed and dried rubber is added in the mixing rolls 7 to 10 per cent. flowers of sulphur. Of course for certain purposes the addition of sul-

phur may vary between 3 and 15 per cent. Careful and uniform mixing is absolutely necessary for the favorable progress of the operation, since the mass must be thoroughly homogenous.

The work is commenced by passing the rubber through between the masticating rolls so as to form it into a loose band; the rolls used for this purpose should allow of being heated by steam. The spongy band thus obtained is again passed through between the rolls, and at the same time is sprinkled with sulphur. When the requisite quantity of sulphur has been applied, it is systematically kneaded in, which is best accomplished by doubling the band together and passing it through between the rolls, repeating the operation until a mass is obtained which to the naked eye appears entirely homogeneous. This mass, however, represents only a mechanical compound of the two substances, a chemical combination not having been formed. It is elastic in the cold, of a brownish color, is but slightly elastic at a higher temperature, and all the sulphur kneaded in can be readily extracted by proper solvents. Freshly-cut surfaces stick together, and this property is made use of for shaping articles from the sulphurized mass which are then subjected to the actual vulcanizing process. Articles may also be made from vulcanized rubber by cementing together the pieces composing them, but the manufacture presents difficulties.

Vulcanizing operation. As previously mentioned, the chemical combination between rubber and sul-

phur takes place only when the mixture of both bodies is heated to a certain temperature. Opinions vary as to the degree of heat required for accomplishing this chemical combination, or vulcanizing as the operation is called, the chief reason for this difference in opinion being due to the fact that the different varieties of rubber do not behave in the same manner. All Asiatic varieties (from the East Indies, Java, Borneo), require less time for vulcanization than the finer qualities of American rubber. The time required for vulcanizing depends on the thickness of the article, as well as on the quality and origin of the crude rubber. Articles with smaller cross-sections are frequently vulcanized in an hour, while thicker articles, and those of larger dimensions, require two to three hours.

Vulcanization is the most difficult and critical operation in the manufacture of rubber goods, since the consequence of a little too much or too little may be over-vulcanization or an insufficient process, and these evils are the more disagreeable since their effect, as a rule, is only noticed when the articles are in actual use. No definite rules can be given in regard to the proportion in which sulphur has to be added, the correct temperature and how long each article must remain in the heater or the press. This must be left to the intelligence and experience of the manufacturer. If the mass to be vulcanized is exposed to too high a temperature, over-vulcanization or burning takes place, whereby the rubber loses its elasticity and

soon becomes brittle, especially upon the surfaces. If the temperature is too low vulcanization is incomplete, and in this case the rubber yields readily to pressure or pull, without, however, rebounding to its original condition when the pressure or pull ceases.

A temperature between 248° and 302° F. may be considered the limit in which vulcanization will progress in a correct manner. In some cases it may be permissible to go above this limit and raise the temperature to 338° F., but only for a very short time.

Experiments have shown that for properly vulcanizing rubber it is necessary to heat it above the melting point of sulphur. Now, as sulphur fuses at 235.4° F., theoretically it would suffice to heat the mass to be vulcanized to somewhat above that temperature. While it is possible to vulcanize rubber at 239° F., this fact is of little or no value for practical purposes, as at that temperature the operation requires more time than the manufacturer can afford.

From what has been said, it will be seen that the temperature for vulcanizing depends chiefly on the conditions under which the manufacturer works. If he works American rubber, and has to vulcanize articles with thick walls, a higher temperature is required than for East Indian material, and articles with thin sides. It is, therefore, advisable not only to work one and the same variety of rubber at one time, but also to subject only articles varying but slightly in thickness to the vulcanizing process at one time.

Vulcanizing apparatus. Generally speaking, brick chambers heated by hot air are now antiquated, and are only used here and there in special cases, for instance, in the manufacture of lacquered rubber shoes and a certain kind of water-proof stuff. The chambers are provided with air-tight doors, and the floor consists of closely-joined iron plates. Several of such chambers adjoin one another, and are heated by one fire. The flues are arranged in such a manner that the fire gases must frequently pass to and fro under the iron plates of the bottoms of the chambers and heat the air in them uniformly.

The articles to be vulcanized are placed upon frames close to the ceilings of the chambers, and the fire is so regulated that the thermometers, which are placed behind glass plates fitted into the doors of the chambers, show as uniform a temperature as possible—266° to 284° F. It may be mentioned here that with the use of this method, complete vulcanization is frequently effected only by adding to the articles to be vulcanized a certain quantity of litharge.

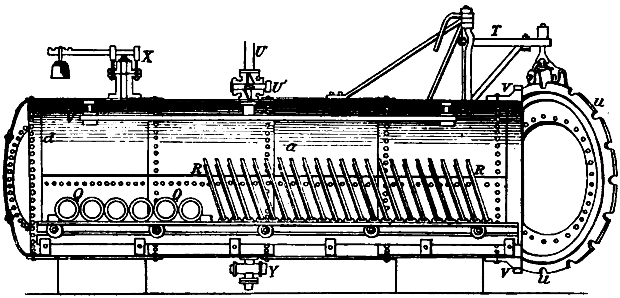
The use of iron boilers with double walls between which steam is introduced to heat the interior space is based upon the same principle as brick chambers.

Vulcanizing heaters and presses, with direct introduction of steam, are now in general use.

The ordinary steam heater is similar to a steam boiler. The size of the heaters varies according to the condition and dimensions of the articles to be vulcanized. Their diameter varies from 3 feet 3

inches to 20 feet, and their length from 6½ to 10 feet, and up to 100 feet and more. The longest heaters are used for vulcanizing hose, because the latter must, as a rule, be vulcanized full length

FIG. 6.



upon the metal cores upon which they have been made. In England the standard length of hose is 60 feet, in France 82 feet, and in Germany 98 feet and 5 inches and even 114 feet and 9 inches. These dimensions indicate the length required for the hose heater.

FIG. 7.

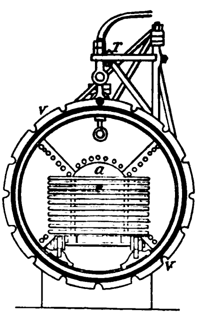
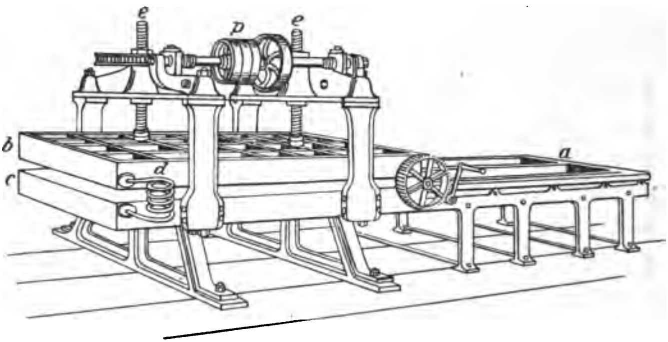


Fig. 6 shows a heater in longitudinal section and Fig. 7 in cross section. The heater *a a* is 16 to 20 feet long and has a diameter of 4½ to 6½ feet, and is constructed like an ordinary steam boiler. In front it is provided with a strong cast iron ring *v v* into which fits a similar ring *u u* of the cover. To make

a perfectly tight joint a tarred hemp rope is laid in the groove of the ring and the lid is then tightened by means of screws. The lid is suspended to a small crane *T*, so that after opening the heater it can be turned to the side, and also be readily replaced. For the convenient introduction and removal of the articles the heater is furnished with two iron rails upon which run small carriages containing the articles to be vulcanized, and besides suitable frames for the reception of the articles may also be placed upon them. *U* is a steam pipe provided with the cock *U'* for the introduction of steam. The steam is uniformly distributed by passing into a long pipe *V*, and from the latter through a number of small holes into the heater. *X*, is the safety-valve, *Y*, the cock for the discharge of the atmospheric air and condensed water. In the illustration are shown at *Q Q* a few iron cylinders filled with buffer rings, and at *R R* frames which serve for holding rubber sheets between iron plates.

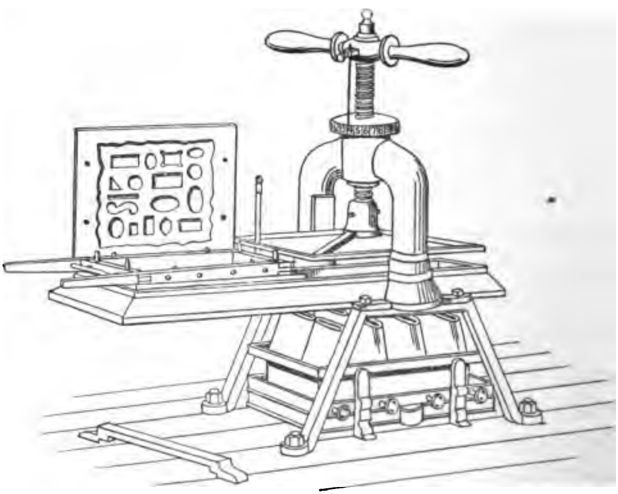
Sheets, belting, large valves, etc., are vulcanized in a press, such as shown in Fig. 8. It consists of two plates, the bottom plate *c*, which is stationary, and the upper plate *d*, which is movable. Both plates can be heated by steam, and their heating spaces are connected by the spiral spring *d*. Steam is introduced from a point on the side of the press not shown in the illustration. The plate *d* can be raised sufficiently by means of the screws *e*, and nuts, which are uniformly moved by a horizontal

FIG. 8.



shaft by means of the pulley *p*, to allow of the support which bears the sheet or belt to be vulcanized, and glides upon the table *a*, being brought between *c* and *d*.

FIG. 9.



A press heated by petroleum is shown in Fig. 9.

It is intended for smaller articles, such as rubber stamps, etc.

Vulcanizing operation. Besides observing the right temperature during heating, the mechanical treatment of the articles is also of great importance. It is not practicable simply to place the articles to be vulcanized in the heater, since in the high temperature to which they must be exposed they would soften to such an extent as to lose their shape. Hence most articles are brought into the heater or press in iron moulds, such being the case with pump valves, buffers, thick rings, bands, cushions for billiard tables, belts, door-mats, balloons, and many other articles. Hose, as a rule, is vulcanized upon metal cores, and the outside is firmly wrapped with strips of linen. The latter are later on removed, and to this is due the tissue-like design frequently seen upon hose and sheets. If entirely smooth surfaces are desired, paper is occasionally used.

For many kinds of goods it is important that the metals forming the moulds should not be readily acted on by sulphur during the heating, as a portion of the sulphur would be abstracted and leave a stain of the metallic sulphide on the goods. Consequently sheets of packing vulcanized in the press are prevented from coming in contact with the metal by sheets of cloth or paper. Tin is the most convenient metal for resisting the action of sulphur. Zinc sulphide being white, indicates the suitability of zinc for coating moulds, etc. All new zinc surfaces should be well cleaned before use. A good

plan is to dust them over with sulphur and talc, and heat them in the heater several times, or they give rise to very troublesome blistering. Boiling with caustic soda helps to prevent this, but it is not certain in its action. Brass moulds should be well tinned. Hard rubber or ebonite forms very convenient moulds, well adapted where metallic surfaces would be objectionable from staining, etc. Stains from tin moulds or tinned surfaces are removed by leaving the vulcanized articles in hydrochloric acid for some time.

To prevent the articles from sticking to the moulds, they are dusted over with talc powder. The talc powder is put in a linen bag, and the moulds as well as the articles dusted over with it. Small curved articles may be placed in tin boxes filled with talc powder, and thus subjected to heating.

Thick sheets are prevented from warping during heating by placing them between iron plates. Thin sheets are dusted over with talc powder, and covered with a linen cloth. In this condition they are wound upon a drum and brought into the heater. Pressed hose and cords are placed in closed or open boxes in talc and then vulcanized.

To avoid loss of time, the articles to be vulcanized should be sorted before heating. The thin and thick should be treated separately, as the latter require more time for vulcanizing than the former.

Many manufacturers effect vulcanizing in two operations. In the first operation, the heater is for

a short time heated only to a temperature not exceeding 284° F. Articles that were too soft to be taken from the moulds acquire by this operation sufficient solidity to be heated by themselves. It is evident that this plan is attended with a loss of time and heat, and that it is more advantageous to finish the work in one operation.

For many articles where it is of special importance that the mass of which they are composed should consist of thoroughly and uniformly sulphurized rubber, the operation of vulcanizing is somewhat modified. The articles are shaped in the usual manner from pure rubber, heated so far as to deprive it of its elasticity, and pressed in moulds. They are then coated with a saturated solution of sulphur in carbon disulphide, and, while still moist, dusted over with powdered sulphur, care being had that the coating of sulphur is uniformly spread over the entire surface.

For articles requiring only light treatment, the following process is sufficient: After being made from pure rubber, immerse the articles in oil of turpentine, and allow them to remain until their surfaces have become somewhat sticky. Then dust them over with finely-powdered sulphur, avoiding an excess of it.

The articles treated with saturated solution of sulphur in carbon disulphide, or simply dusted over with powdered sulphur, are vulcanized in the same manner as articles of sulphurized rubber. Thin articles, when prepared with sufficient care, become

in this manner thoroughly vulcanized, but thicker articles do not, the product not being uniform. A cross-section will show plainly that only the surface is vulcanized, the interior parts remaining unaltered.

In the manufacture of the various red colored rubber articles, hose, combs, etc., vulcanization is effected by an addition of pentasulphide of antimony. The preparations of pentasulphide of antimony for this purpose found in commerce differ, however, very much in their action in so far that in vulcanizing, one kind gives always the desired red coloration, while another, which is not appreciably distinguished from it by color or content of sulphur, frequently or always yields a faulty product which shows itself by the color turning, or stains upon the surface. The cause of this difference in behavior of the pentasulphide of antimony is not yet known.

Turner fuses bismuth 5 pounds and lead 5 pounds, mixes them, compounds the mixture with half its weight of sulphur, pulverizes after cooling, and mixes 10 pounds of the compound with 30 pounds of rubber. The articles vulcanized with this mixture are said to stand a temperature of 392° F.

CHAPTER IV.

RUBBER COMPOUNDS.

FOR the manufacture of articles which are to possess in a very high degree the property of elasticity combined with toughness the use of pure sulphurized rubber, *i. e.*, a mass which has been prepared from pure rubber and sulphur according to one of the methods described, is absolutely necessary. In some cases, however, elasticity is not so much required as cheapness of production, for instance toys for children, little cups, saucers, tubs, etc. Such articles contain a very small proportion of rubber, but many admixtures.

The substances used as admixtures depend on the properties the articles are to possess. If a light color and little weight is desired, either fine white pipe-clay, chalk, or magnesia is mixed with the mass to be vulcanized. For white masses of greater weight, oxide of zinc is used, or sulphate of lead which, being a waste product of chemical factories, can be procured at a comparatively small cost.

Cinnabar, round lake, sesqui-oxide of iron (caput mortuum, colcothar) are generally added to produce a red color; ultra-marine or smalt may be used for blue; chrome yellow furnishes the yellow color; a

mixture of chrome yellow and ultra-marine, green; colcothar and ultra-marine, violet, etc.

Uniform coloring can only be effected by carefully kneading the coloring matter into the rubber compound. But it can also be uniformly colored by producing certain chemical combinations in the mass itself, and some receipts for that purpose, applicable to rubber as well as gutta percha, are here given.

For *black* a fluid is used consisting of:

Blue vitriol	1 lb.
Water	11 lbs.
Caustic ammonia . . .	1 lb.
Muriate of ammonia . .	½ lb.

The blue vitriol is dissolved in water together with the muriate of ammonia, and the caustic ammonia is then added.

For *green* the following are used:

Blue vitriol	½ lb.
Muriate of ammonia . .	1 lb.
Burned lime	2 lbs.
Water	11 lbs.

For *violet*:

Blue vitriol	¼ lb.
Sulphate of potassium . .	1 lb.
Phenicine	¼ lb.
Water	11 lbs.

The articles to be dyed are boiled in their respective fluids from 15 to 30 minutes, but articles somewhat thicker must be boiled for a longer time to make the coloring uniform. The dyed articles can then be vulcanized in the usual manner.

Rubber compounds which require to be rough are mixed either with powdered pumice-stone or the finest drift sand. The last two are added to the mass at the time when the sulphur is kneaded in, or in case the process of vulcanizing with a fluid —chloride of sulphur—is used, they are added to the pure rubber. To insure a completely uniform combination of the added ingredients, as clay, magnesia, pumice-stone, etc., it is absolutely necessary that they should be powdered as fine as possible, carefully washed, and then thoroughly dried, as the presence of moisture is very detrimental.

White or black pitch is also added to the rubber mass for the purpose of manufacturing cheap products; although many manufacturers assert that the properties of the product are essentially improved by such additions. This assertion, however, is not true, and is probably only made for the purpose of hiding the real object of these admixtures, namely, the production of masses in a cheap manner. In the following some receipts are given for preparing rubber compounds. These receipts have been tried and found useful.

White rubber masses.

	Parts by weight.
Rubber	100
Sulphur	10 to 20
Chalk	40 to 60
Magnesia	5 to 40
Oxide of zinc	20 to 30

If the composition is to be colored, the coloring agent takes the place of one of the other components, either of chalk, magnesia, or oxide of zinc. This compound stands vulcanizing at a high temperature and can be finished in one operation.

Cheap Rubber masses with an addition of Resin.

	Parts by weight.		
Rubber . . .	100	200	200
Sulphur . . .	25	25	50
White pitch, or . .	15	18	25
Pine resin . . .	12	60	20

Masses prepared with an addition of pitch or resin cannot stand a high vulcanizing temperature. When heated from 284° to 302° F. they become so soft that the mass would collapse over the mould. Therefore in vulcanizing it should only be heated very little above the melting point of sulphur, 235.4° F. A temperature between 239° and 248° F. will be most suitable for the purpose. Thinner articles prepared from these masses are quite elastic, but thicker ones are less so.

The Franco-American Rubber Co. prepares *metallized rubber* by mixing rubber with pulverized metallic lead, zinc, or antimony, and vulcanizing in the usual manner.

For the preparation of vulcanized rubber which does not swell up when brought in contact with fat, Schwanitz, according to a patent granted to him in Germany, uses Para rubber 6 lbs., whiting 6 lbs., glycerine of 1.23 specific gravity 1 lb., litharge 3½ ozs., and flowers of sulphur 7 ozs. The mass is worked between heated rolls and exposed in a glycerine bath to the action of steam of a tension of 2 or more atmospheres.

To make rubber pervious to perspiration in the use for articles of clothing, Scharff mixes it before vulcanizing with 10 per cent. of wood cellulose, the sulphur being added at the same time.

Gerner mixes rubber and gutta-percha with camphor, cowrie copal, mustard or hemp seed, freed from oil and ground.

For the manufacture of hard rubber articles the camphor and copal are separately ground in rolls. Then as much flowers of sulphur as is required for the articles to be manufactured is added, for instance, 1 lb. of sulphur, with ¼ lb. of camphor and ¾ lb. of copal. Before adding the rubber the mixture is finely ground and forced through a fine sieve. In working the materials are moistened with naphtha, gasoline or benzine. The quantities of camphor and copal to be used in the various mixtures for hard and soft rubber products depend on the kind and

qualities of the articles as well as on the purpose for which they are to be used. For special kinds of hard rubber are preferably used ½ lb. of the camphor and copal mixture, while for other kinds ½ or ¼ of this quantity suffices. For soft rubber mixtures the composition and treatment of the mixture are the same except that less sulphur is required.

In vulcanizing, the temperature has to be gradually raised with great care. The mass, however, requires heating a shorter time than ordinary hard rubber, four to five hours being sufficient according to the thickness of the articles. During the last two hours the temperature is to be raised to 313° to 320° F. In vulcanizing soft rubber it is best to heat for the same length of time as in the ordinary process. The temperature should be raised at least to 280° F., and in many cases to 313° to 320° F. The larger the content of camphor and copal, the higher must be the temperature.

Kamptulicon. The composition known by this name is especially well adapted for the manufacture of floor cloths subjected to hard usage, for coating articles, etc. Genuine kamptulicon consists of an intimate mixture of rubber and powdered cork, and is prepared as follows:

Waste of cork, and old corks also, are cleansed by washing several times in water. The washed and well-dried mass is comminuted by grating upon a drum provided with small teeth like a rasp, and then ground into a fine powder.

The rubber is cleansed in the usual manner, and

rolled into thin bands between closely-set rolls. The bands are strewed uniformly with the powdered cork, and then subjected to further treatment. This is done in the same manner as described for preparing sulphurized rubber, that is, by rolling, kneading, and repeated rolling until an entirely homogeneous mixture has been formed. Finally, sheets 0.0787 to 0.1968 inches thick are formed, and these are covered either on one or both sides with a coat of good linseed-oil varnish or oil paint. Of course, with the assistance of oil paint, sheets with various patterns (carpet and parquet designs) can be produced.

Powdered sulphur may also be incorporated with the rubber besides powdered cork, and the articles may be subjected to heating after they have been formed, and in this manner a vulcanized kamptulicon is obtained.

The principal advantages of kamptulicon are that with very little weight it combines great elasticity, and, for this reason, is well adapted for floor covering in passage-ways, where the noise made by walking is to be prevented as much as possible.

Kamptulicon can be used as a block cushion under stamping presses to weaken the shock, but it should be inclosed in an iron ring to prevent splitting. It serves also to make wheels for polishing brass, steel, German silver, and other metals. This is done by covering a wooden disk with a piece of kamptulicon of the proper size.

A uniform color can be made to permeate the entire mass, which can be worked into a kind of

mosaic in floor coverings. This condition is obtained by incorporating the coloring matter with the rubber. Colcothar, ultra-marine, lamp-black, etc., etc., are used for this purpose. The masses colored by any of the above substances are rolled out, and it is then a very easy matter to cut stars or other designs from them by means of a sharp knife or a suitable die, and to combine these into any desired pattern. As the matter is colored through and through, floor-cloths, or other articles manufactured in this manner, retain their beauty as long as the articles themselves last.

Rubber leather. Generally speaking this is identical with kamptulicon, although it is sometimes manufactured in a different manner. While genuine kamptulicon is always composed of rubber and cork, rubber leather freqnently contains, instead of cork, any kind of fibrous substance, such as hemp, flax, jute, etc. It is generally manufactured as follows: Rubber mostly in the form of small waste pieces, of which there will always be large quantities in rubber factories, is either entirely dissolved by a solvent or at least allowed to swell up very much. The fibrous substance is then incorporated with the mass, and the latter is made homogeneous by long-continued rolling.

The easiest way of incorporating the fibrous substance is by stirring as much of it into the half-fluid mass of rubber and solvent—refined petroleum being the best for this purpose—as can conveniently be done. The mass is then placed upon a table, which

is quite thickly strewn with fibrous substance, and rolled into a cylinder. When in this manner a mass has finally been obtained, which possesses sufficient consistency to allow of it being worked between the rolls, the incorporation of fibrous substance is continued there until a sufficient quantity of it has been kneaded in to impart a suitable degree of solidity to the mass.

It is advisable to repeatedly form the bands, which have been obtained by rolling, into lumps, and to pass these again through the rolls, as by these means the fibres are piled in different directions (forming, so to say, a kind of felt), and by doing this the solidity of the substance will be considerably increased.

As far as solidity and tenacity are concerned, rubber leather surpasses by far kamptulicon; but the latter is softer and more elastic. Kamptulicon being rather expensive, it has been largely superseded by linoleum, which is manufactured from a mixture of cork-meal, linseed oil and small additions of resins.

Balenite or artificial whalebone is a material, as indicated by the name, intended to serve as a substitute for genuine whalebone. A mass to answer the intended purpose must possess considerable elasticity as well as solidity—must, therefore, be a medium between soft and hard rubber. A mass answering the purpose very well is prepared according to the following formula:

	Parts by Weight.
Rubber	100
Ruby shellac	20
Calcined magnesia . . .	20
Sulphur	25
Pentasulpide of antimony . .	20

The foreign substances are incorporated with the rubber, the mass is pressed into moulds, generally plates or prismatic bars, and vulcanized at a moderate heat. The mass which is thus obtained may serve in all cases as a substitute for the genuine whalebone, and may also be used for bobbins, etc. On account of its light weight and indestructibility, balenite may be highly recommended for the manufacture of gunstocks, as also of elastic plates and splints for surgical purposes.

Plastite. This substance resembles hard rubber, but differing from it in being non-elastic, although quite hard. As it can be brought into any shape desired, and is largely composed of inexpensive substances, it is especially adapted for the manufacture of pressed ornaments, small frames, boxes, heels of shoes, etc.; in short, for all purposes for which wool, metal, horn, etc., are used.

Coal-tar asphaltum is an important component of plastite. It forms a deep black, shiny and hard mass, and is gained in the distillation of coal-tar, as residuum after all volatile substances have been distilled off. Besides coal-tar, asphaltum, sulphur, and magnesia, and sometimes pentasulphide of antimony form a part of plastite.

Magnesia can be very well replaced by other indifferent substances, such as finely powdered and washed chalk, etc., but the use of magnesia, which is a very light substance, offers the advantage that the masses can be made of great volume, and at the same time of little weight.

A plastite mass possessing very good properties may be prepared according to the following formula:

	Parts by Weight.
Rubber	100
Sulphur	20 to 25
Magnesia	40 to 50
Pentasulphide of antimony .	40 to 50
Coal-tar asphaltum . .	50 to 60

The foreign substances are incorporated with the rubber in the usual manner. The separate articles are pressed in hot iron moulds, and are then heated. On account of its great hardness and solidity, plastite takes a high degree of smoothness and polish, and for this reason is well adapted for the manufacture of handles for umbrellas and canes, door-knobs, etc.

Grinding and Polishing Compositions.—Rubber possesses the specific property of holding foreign substances, once incorporated with it, very tenaciously. If the incorporated substances are hard, the mass is suitable for grinding or sharpening; if soft, the composition serves for polishing. The first category includes powdered pumice-stone, powdered glass, quartz, sand, emery. To the second class belong colcothar, graphite, talc.

Below several formulæ are given, which have been highly recommended, especially for sharpening and polishing knives:

I.

	Parts by weight.
Rubber	280
Powdered emery	1120
Lampblack	$6\frac{1}{3}$

II.

	Parts by weight.
Rubber	280
Graphite	512
Lampblack	$6\frac{1}{3}$

III.

	Parts by weight.
Rubber	280
Graphite	488
Lampblack	$6\frac{1}{3}$

IV.

	Parts by weight.
Rubber	280
Zinc-white	84
Yellow ochre	1120

V.

	Parts by weight.
Rubber	280
Sulphur	84
Powdered emery	1120

As will be seen, formulæ I. and V. contain emery, which, on account of its hardness, serves as a grinding agent. The addition of lampblack in the other compositions is not essential, as the only object of it is to give them a black color. Nos. II. and III., on account of the percentage of graphite they contain, must be considered as polishing compositions; and No. IV. also possesses the same property.

It has been endeavored to prepare compositions which shall answer for one or the other purpose; but one suitable for grinding, and at the same time for polishing, can only be prepared by using a hard body in the form of an impalpable powder, equaling in fineness the very finest flour.

Graphite and talc, which of course must be powdered as finely as possible and washed, are especially adapted for polishing compositions. The rubber is mixed with 150 to 200 per cent. of this powder, and the entire mass is vulcanized by adding 10 to 15 per cent. of the weight of rubber of sulphur to it, and subjecting it to the heating process.

Grinding compositions may be prepared by using powdered glass, pumice-stone, flint, or emery. The masses containing powdered glass or pumice-stone, being the softest, may be used for grinding brass or bronze, and those containing powdered flint, for grinding steel. The masses containing emery may be even used for grinding precious stones, as emery is the hardest body next to the diamond.

To change the hard bodies—glass, flint, and emery—into fine powder, it is necessary to make

them red hot, and to throw them while in this condition into cold water. They become very brittle in consequence of the quick cooling off, and can then be ground into fine powder without great difficulty.

If the grinding composition is to be subjected to considerable wear, it is advisable to add to the rubber, besides the powder of the hard body, some sulphur, and to heat the mass sufficiently to change the rubber into hard rubber.

It is merely a matter of choice what form is to be given to the grinding and polishing compositions. Revolving circular disks, against which a piece of vulcanized rubber is pressed, are very suitable for sharpening and polishing table knives. If a knife is placed between the disk and the piece of rubber it will appear polished or ground after a few revolutions of the disk.

For manufacturing purposes, especially for metal workers, it is best to give to the grinding or polishing masses the form of ordinary grindstones, that is, that of circular disks.

The quantity of powdered hard substances to be incorporated with the rubber, may be a very large one, especially if hard rubber is used, and may amount to as much as four times its weight.

Rubber enamel. Hard rubber, on account of its elasticity and toughness, is well adapted for coating articles of metal which are to be protected against rust. For the purpose of coating metal with a thin layer of hard rubber, it is brushed over with a solu-

tion of rubber in benzine or petroleum, and is then dusted with powdered sulphur. Both operations are repeated after the first coat has become dry. The articles coated in this manner are quickly heated to a temperature of from 320° to 338° F., when the well-known reciprocal action between sulphur and rubber takes place, and they will come out with a coat of hard rubber. Defective places in the coating can be repaired by repeating the brushing over with the rubber solution, dusting with sulphur and heating.

If it is desired that the coat should show an entirely uniform black color, it is advisable to dust the article with a fine black pigment after it has been dusted with sulphur. Frankfort black can be especially recommended for this purpose, as it forms an entirely dry powder which can be readily and completely dusted away, which is not the case with the majority of black pigments, for instance, lamp-black, as more or less tarry matter always adheres to them.

The following process may be recommended for preparing colored enamels of somewhat greater thickness. An entirely clear, but rather thick solution of rubber is prepared. This is intimately mixed with about 12 per cent. of the weight of the rubber originally used of the finest powdered sulphur and the coloring substance to be incorporated. The mass obtained in this manner should have a consistency equal to thick oil paint. Should it be too thick to allow of it being evenly applied with a

brush, it may be reduced with oil of turpentine, or, in case it is too thin, this may be remedied by an addition of coloring matter.

If benzine or carbon disulphide has been used as a solvent, it will be very difficult, on account of the great volatility of these fluids, to evenly apply the mass with a brush. It is therefore best to allow the rubber to swell up in benzine or carbon disulphide, and effect complete solution with oil of turpentine or rectified petroleum.

Bristle brushes are used to coat the articles with the composition, and it should be done in thin but frequently repeated applications. If a white basis mass is used marbled designs can be produced by using yellow, red, or blue. The beauty of the work will of course depend on the skill of the workman.

When the entire coat is finished it is dried, which can be accelerated by exposing the article to a temperature not exceeding 212° F. In case the enamel shows defective places it is repaired and finally heated at a temperature of 320° F. The rubber enamel manufactured in this manner adheres very tightly to metal, and will take a very high degree of polish. As it will stand a temperature of over 392° F., it can be advantageously used for enameling the exteriors of self-feeding stoves, etc.

Deodorizing vulcanized rubber. All articles manufactured from vulcanized rubber possess a disagreeable odor, perceptible even after the articles have been in use for months. As this odor is very repugnant to some persons, who will not use rubber

articles simply for this reason, it becomes a matter of importance to remove this objection, especially with articles intended for personal use—pocket books, cigar cases, etc.

Vulcanized rubber may be deodorized in various ways: The articles are either exposed to a constant high temperature, or are treated with animal charcoal. While heating will remove the odor, to get entirely rid of it, it must be continued for many days, and this method is, therefore, not available in practice. On the other hand, animal charcoal possesses in a high degree the property of absorbing odor. For the purpose of deodorizing rubber it should be used in the form of powder.

A large number of articles may be deodorized at one time by treating them as follows: Cover the bottom of a sheet-iron box about $\frac{3}{4}$ inch deep with powdered animal charcoal, upon which, place the articles. Fill in the spaces between them with animal charcoal and cover with a layer about $\frac{3}{4}$ inch deep. Upon this another layer of articles is laid, and so on, until the box is filled, when it is placed in a room having a temperature of from 140° to 176° F., and left there from 3 to 8 hours, according to the size of the box.

During this time the animal charcoal absorbs the odor, and the articles become entirely deodorized. But they must be stored in a special room, as they would again absorb the odor if stored with articles not deodorized. In the course of time, the animal charcoal loses its deodorizing ability and

must be replaced by fresh material, but it can be regenerated by calcining. This is done by placing it in a sheet-iron cylinder about 20 inches long, and closed on both ends by tight-fitting covers. The upper lid should have a hole the thickness of a straw to allow the gases to escape. The animal charcoal, after it has been thoroughly calcined, must be allowed to cool off before the cylinders are opened, as it would burst into flame and be consumed if exposed to the air while hot.

Desulphurized vulcanized rubber. As previously mentioned, only a small portion of the sulphur—about 1 to 2 per cent.—combines chemically with the rubber, the greater portion being only mechanically mixed with it. This sulphur, however, becomes effective in time and causes the articles to become brittle and hard after long storage. This defect will show itself especially in rubber hose, which becomes so hard that it will break when an attempt is made to bend it. To prevent this evil the excess of free sulphur is removed by boiling the vulcanized rubber in caustic soda or caustic potash lye, whereby the free sulphur is gradually dissolved, while the chemical combination of sulphur and rubber is not attacked.

The time required for boiling depends on the strength of the lye used and on the quantity of free sulphur present. The best plan is to take occasionally a piece of the rubber from the boiler and by it test the progress of desulphurization. The color of desulphurized rubber closely resembles that of the

ordinary product. Therefore, as long as the piece shows the characteristic grayish coloring of ordinary vulcanized rubber, the mass is not properly desulphurized, and the boiling must be continued.

Vulcanized rubber, from which the excess of free sulphur has been properly removed, only requires washing and drying after it has been taken from the lye, and is then a product which may be called the most perfect of all rubber preparations, as it remains not only entirely soft and elastic in all temperatures, but does not become hard even if stored for a long time, and has no odor whatever. It is well adapted for manufacturing articles for surgical or scientific purposes or to be used in the nursery or sick-room —nursing nipples, rubber cloth to protect bedding, etc. It is also an excellent material for gas-tubing, as it combines great pliability with perfect impermeability to gas.

CHAPTER V.

HARD RUBBER.

It has previously been mentioned that when vulcanized rubber contains too much sulphur, and is exposed to a higher temperature for a longer time than necessary for vulcanizing, it becomes hard and horn-like. Hancock observed this at an early date, and makes mention of it in his first patent-specification. Goodyear continued the experiments, and some years later patented a method for manufacturing, from rubber and gutta-percha, with the addition of other substances, articles which were formerly made of wood, leather, metal, etc., and which at the same time were lighter and cheaper.

Generally speaking, the preparation of hard rubber is based upon the same principles as that of vulcanized rubber. The crude rubber is softened, washed, dried, macerated, mixed, according to circumstances, with other specially suitable varieties of crude rubber, and compounded with sulphur and other ingredients. The addition of sulphur may amount to as much as 50 per cent. In place of pure sulphur, other sulphur combinations, such as sulphide of antimony or sulphide of lead, can be used. Goodyear has recommended a zinc compound, which is prepared as follows: Solution of zinc sulphate or

acetate is precipitated with solution of liver of sulphur, either direct or after the latter has been decolorized by the introduction of sulphurous acid. The precipitate thus obtained is thoroughly washed with water and used after drying.

Besides sulphur, other substances such as zinc-white, whiting, magnesia, etc., may be added to the mass while being treated in the rolls, the proportion of such additions depending on the demands made on the finished material as regards elasticity, flexibility or hardness, as well as color. The preparatory operations require still greater care and attention than in the preparation of soft rubber, as a very small quantity of water and very small air bubbles enclosed in the mass may make it porous or even entirely ruin it in consequence of the high temperature to which the material is later on exposed.

Hard rubber is used in the manufacture of many articles, such as combs, spindles, shuttles for spinning and weaving, cigar and match cases, valves, pumps for corrosive fluids, surgical instruments, etc.

The rubber, sulphur and other ingredients are combined between mixing rolls, the operation being continued until a thoroughly homogeneous mass has been formed, which has the consistency of dough, and can be shaped into all possible forms.

The prepared crude mass is rolled into plates of various thicknesses, and the separate articles made from them by pressing in moulds. Small boxes, spectacle cases, etc., are moulded over solid cores.

Sometimes larger sheets are rolled out, vulcanized, and then worked like wood or horn, with a lathe, or saw and plane.

To prevent, in filling the moulds with the prepared mass, air bubbles from remaining between it and the mould, Engel, according to a German patent, first fills the mould with linseed oil, then presses the prepared rubber mass into the mould so that in vulcanizing, the small remaining portion of the oil is absorbed by the rubber.

Vulcanizing hard rubber requires either one or two operations. If ordinary articles or simple sheets are to be treated, one operation suffices, but for more complicated shapes it is advisable to perform the work in two operations.

If vulcanizing is to be done at one operation, the articles are placed in the heater, and heated for several hours—three to six—at a temperature of 302° F. Manufacturers differ in their statements about the degree of heat, but these are of little value, as every practical man will soon find out for himself. It is stated, for instance, that especially excellent properties are given to hard rubber by first heating it for two hours at 230° F., then quickly raising the temperature to 302° F., and keeping it there for several hours.

By this process articles are obtained sufficiently vulcanized, as a temperature of 302° F. suffices to convert quite thick objects into hard rubber in the course of several hours, but it is difficult to understand the object or effect of heating them for two

hours at 230° F., as sulphur, as is well known, only fuses at 235.4° F., and it is scarcely worth while to talk about sulphur producing any effect before it is melted. By special experiments in this line it has been ascertained that, even after the mass had been heated for several hours at a temperature of 230° F., by far the greater part of the sulphur could be extracted from it in an unaltered state by a solvent, this being a sure proof that no *chemical* action had taken place.

Hard rubber suffers considerable contraction in the course of vulcanizing, and the shrinkage of the articles allows of their removal from the moulds by a gentle tap. The shrinkage being uniform, owing to the even temperature, the articles do not warp.

Articles of a not especially complicated shape may be vulcanized without the use of a mould. Flat articles may be treated without further preparation by laying them upon iron plates, but if other articles are to be vulcanized without the use of moulds, it is advisable to dust them over with magnesia or powdered chalk, and to place them in sheet-iron boxes filled with fine sand in such a manner that the articles are completely covered by it on all sides. The sand prevents the articles from collapsing during the first period of heating, an event which it would be very difficult to avoid without it.

By the above process skilled workmen can vulcanize and finish in one operation quite complicated articles, with a very small percentage of defective

products. However, to prevent any possible failure it is advisable to divide the vulcanizing process into several operations.

In this case the first operation, at a temperature of about 293° F., lasts but one hour. The articles then acquire a considerable degree of solidity, and can be taken from the moulds to undergo inspection. The perfect pieces are immediately put back in the heater and finished without further manipulation, but those showing defective places, cracks, holes, etc., are repaired with a dough-like mass of rubber, and heated for another hour, when they are again inspected and repaired, if necessary, and heated for another hour—this alternate inspection, repairing, and heating being continued until the articles can pass for finished goods.

Hard rubber, prepared from crude rubber and sulphur only, has a black color, and takes a very high degree of polish. Articles manufactured from this material, although black, can also be colored any desired shade.

A distribution of the coloring substances through the entire mass has the advantage of considerably increasing its weight, but it also, to a great extent, injures its properties. To give hard rubber any desired color without altering its internal properties two methods, which may be designated as "*dusting*," and "*plating*," or "*enameling*," are made use of, both being well adapted for the purpose.

Dusting is done as follows: After the article has been shaped from the prepared crude material, it is

thickly dusted over with a finely-powdered coloring matter contained in a linen bag. The mould into which the article is to be pressed must first be uniformly dusted over. After vulcanizing the article should show a uniform coloring. Any defect is repaired by repeating the dusting over and reheating.

Articles of an entirely uniform color can be obtained by *plating* or enameling as follows: A mass is prepared from crude rubber and sulphur in the usual manner by rolling, the coloring matter being at the same time incorporated with it. Rolling is continued until a uniformly-colored paste is obtained.

The paste thus colored is rolled into a sheet about half as thick as the sheet to be enameled, and if only one side of the latter is to be treated, the two sheets are laid one upon the other and rolled out to the thickness required for the articles to be made.

If the rubber is to be enameled on both sides, a plain sheet is placed between two colored ones. In this manner a different color may be provided on each side, and an enamel of any desired thickness applied. The thinner the enamel, the thicker, of course, the enclosed plain sheet must be.

Frequently the smaller portion of articles called hard rubber consists of actual rubber, various indifferent substances, such as chalk, magnesia, zinc-white, etc., being added for the purpose of increasing the weight. If these admixtures are intended to impart a certain color to the rubber, care must be had not to use a coloring matter which may be

affected by sulphur, otherwise the coloring may turn out the reverse of what was intended. For this reason coloring substances containing lead, such as white lead, chrome yellow, etc., must be avoided, since lead readily combines with sulphur, forming black sulphide of lead, and in this case black instead of white or yellowish masses would be obtained. What has been said about lead compounds, applies also to coloring substances containing copper.

Lakes, prepared from organic substances and alumina, as well as zinc colors, may be used for coloring hard rubber without any further preparation, except that the lakes must be perfectly dry before they are incorporated with the mass. If used moist, the water contained in them is, during the vulcanizing process, converted into steam and the bubbles thus formed cause the mass to bulge up and the surface to become rough, while the interior will not be compact but porous.

The waste resulting in moulding the articles is immediately kneaded together, passed through between the rolls, and may then be used in the manufacture of other articles. But the waste from hard rubber, *i. e.*, after it has been vulcanized, can only be utilized for the preparation of lacquer, which will be referred to later on.

The best plan is to shape the articles by pressing or stamping them from the mass, as there is much less waste than when preparing sheets from which the articles are to be manufactured.

The hardness and elasticity of hard rubber prin-

cipally depend on the quantity of sulphur which has been added to the crude material. Below a few receipts adapted for the purpose are given.

Articles sufficiently elastic and pliable, so that they will not break, even when sharply bent, can be made from the following composition:

	Parts.
Rubber	86 to 88
Sulphur	14 to 12

This is especially well adapted for manufacturing combs and such thin articles as are to possess a high degree of elasticity and considerable solidity.

By mixing together:

	Parts.
Rubber	76 to 80
Sulphur	24 to 20

a mass is obtained which, in regard to elasticity, is nearly equal to the foregoing, but is somewhat more fragile.

The larger part of the articles, as combs, etc., sold as hard rubber are made of a composition resembling the latter, but containing more sulphur and consequently are much cheaper.

Ebermayer has examined hard rubber combs from various factories and found that their elasticity is conditional on the content of sulphur. Thus a mass with 11.95 per cent. sulphur could be readily bent but not broken, while a mass with 21.46 per cent. could be broken only with difficulty, and one containing 28.25 per cent. was extremely brittle and hard.

When great hardness and solidity, with but little elasticity are required, as in a material suitable for knife handles, rollers, buttons, tool handles, door knobs, lock plates, etc., the percentage of sulphur is increased and—

	Parts.
Rubber	65 to 76
Sulphur	35 to 24

form the best compositions for such purposes.

It is a remarkable fact that some resins, although quite brittle by themselves, impart a certain elasticity to hard rubber. Shellac is especially effective in this respect. It can be used either bleached or unbleached (the so-called ruby shellac). The latter is to be preferred for articles of a dark color, as it is far cheaper than the bleached article, and answers the purpose equally well.

The shellac should be powdered as fine as possible, and intimately mixed with the rubber by continuous rolling. A piece of shellac large enough to be visible to the naked eye would be sufficient to spoil the appearance of the article. Hard rubber will bear the admixture of a large quantity of shellac, and in some cases an amount equal to that of the crude material may be used.

A composition consisting of:

	Parts by weight.
Rubber	88
Sulphur	12
Shellac	50

was formed into sticks having a cross section of 0.155 square inch, which could be bent to a considerable extent after they had been vulcanized, but were at the same time so elastic that the sticks always sprung back to their original straight form. The rubber was so hard that thin shavings could be cut from it only with a very sharp knife. In consequence of these properties this variety of hard rubber furnishes an excellent material for the manufacture of bobbins and shuttles, as these can be made so thin that their sides are scarcely thicker than thin paste-board.

Hard rubber can be used with great advantage for making bowls for silver-plating baths, spatulas, rollers and other utensils used by photographers, also for stoppers and caps of bottles containing corrosive fluids.

Newton prepares buttons, knife handles, etc., by mixing gutta percha, with or without rubber, with an equal weight of sulphur and exposing the mixture to a temperature of from 248° to 302° F. For every pound of gutta percha may be added $\frac{1}{3}$ to $\frac{2}{3}$ lb. of a mixture of chalk, gypsum, shellac and resin.

Johnson uses a mixture of sulphur 1 part, zinc oxide 9 parts, and rubber 9 parts for the manufacture of brushes, curry-combs, etc.

Hard rubber is much used in the manufacture of black ornaments, such as brooches, earrings, bracelets, chains, etc., which resemble jet and even onyx, when finely polished. But as the pieces come more or less dull and dead from the moulds, they

require polishing, which is done either upon the lathe or by means of cloth or felt wheels, and sometimes with the use of a fine polishing agent. Since this mode of polishing considerably increases the cost of the articles, it has been endeavored to find a process which renders polishing entirely superfluous or at least facilitates it. The use of glass moulds or lining the iron moulds with thin tin-foil has yielded good results in this direction.

Many rubber articles require a combination between hard and soft rubber, between soft and semi-hard, semi-hard and entirely hard, or between all three. Such problems are, for instance, presented in lining iron boilers intended for the reception of acids (montejus), in the fabrication of coatings for rolls, especially of larger dimensions, such as are used in the manufacture of paper and leather, and in finishing cotton goods, and in the manufacture of many other smaller articles. The correct and suitable solution of such problems requires besides close supervision of the workmen, very careful selection of the varieties of crude rubber and admixtures to be used, as well as many years' experience in vulcanizing.

The physical and chemical properties of hard rubber are entirely different from those of crude rubber. It is black, entirely without odor, horn-like, and not unlike hard wood or ivory. It is dielectric, but becomes electric by vigorous rubbing. Cold water, light and atmospheric air, have no effect upon it. It does not oxidize. In boiling

water, however, it becomes soft and flexible. Towards solvents, which completely dissolve crude rubber and partly vulcanized soft rubber, it is entirely indifferent, and it resists acids to a high degree. Exposed for some time to dry temperatures of above 392° F., it does not become first sticky like natural crude rubber, nor melt like soft vulcanized rubber, but commences to carbonize without having yielded an intermediate product.

Preparation of artificial ivory. For many years chemists have endeavored to prepare a substance to serve as a substitute for ivory, which is every year becoming scarcer and dearer. Their attention was principally directed to compositions with glue as a base, to which were added finely powdered white substances, and such bodies as would make the glue insoluble; the salts of alumina and tannin being chiefly used for this purpose. It cannot be denied that the process of preparing such masses has been successful as far as their external appearance is concerned, it being scarcely possible to distinguish them from genuine ivory. But they lack one of the principal properties of the genuine article, namely that of combining great elasticity with solidity.

It has been tried to utilize rubber for preparing a mass which would possess as nearly as possible all the properties of ivory, and these experiments have been so successful that substances are now obtained which can be employed for manufacturing a large number of articles formerly made of ivory. But

they cannot take the place of the genuine material where elasticity combined with great solidity is a requisite. Many attempts have been made to manufacture billiard balls from such composition, but they have never been very successful, the balls in a short time becoming full of cracks, and breaking even when but gently struck.

For the preparation of an elastic mass a certain percentage of pure rubber must be added, but the resulting product is not of a sufficiently light color.

It may here be mentioned that many products are sold as artificial ivory which contain but a small quantity of rubber or gutta-percha, foreign substances, which impart weight, being the chief components. The same may be said of compositions sold as hard rubber which contain less than 33 per cent. of rubber.

Every imaginable kind of bleaching agent has been tried and recommended for decolorizing and bleaching rubber, but no process has been entirely successful, and it may justly be said that with the means at present at our command it is impossible to obtain results entirely satisfactory. If rubber be treated with a bleaching agent which exerts any kind of effect upon it, it will acquire a lighter color—a very light yellowish-brown—but a chemical change will at the same time take place, and the mass bleached, for instance, with chlorine, cannot be called rubber any longer.

Several methods have been published, by which it is claimed rubber can be bleached without suffer-

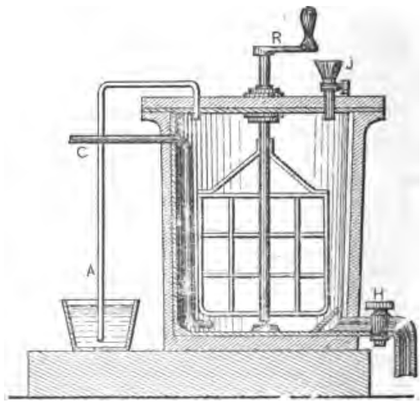
ing a chemical change; but on testing these methods, the result was always the same, namely, the bleached product did not possess the properties of rubber. Nearly all these methods amount to the same thing, namely, that the rubber is allowed to swell up very much—complete solution not being necessary—and chlorine be introduced into the swelled-up substance. The most suitable solvents for the purpose are carbon disulphide, benzene and rectified petroleum, though chloroform and oil of turpentine have also been recommended.

For treating rubber with chlorine a special apparatus is required. This consists of a wooden vat lined with lead. It should have a lid or cover lined with lead and capable of being secured air-tight. In the centre of the lid or cover is a revolving shaft connected with a stirring apparatus made of leaden rods. The pipe conducting the chlorine reaches to the bottom of the vat, and a funnel provided with a stop-cock is fitted into the cover to admit new fluid when required. A small pipe is fitted into the cover and passed into a tank of water adjoining the vat, for the escape of the chlorine. Fig. 10 shows the arrangement of the apparatus. The chlorine enters through C; R is the stirring apparatus; J is the funnel; A the escape pipe for the chlorine; H is a stop-cock in the bottom of the vat, covered inside with a leaden sieve.

The rubber, cleansed and cut in small pieces, or, still better, in shreds, is placed in the vat, which is then closed, and the solvent poured in through the

funnel J. The stirring apparatus R is started and kept in motion until solution is complete. The chlorine is then introduced and allowed to flow until its escape is noticed from the pipe A. Alcohol equal in volume to that of the solvent is introduced into the vat through the funnel J, which

FIG. 10.



causes the bleached rubber to be separated and precipitated in a slimy condition. The solution is constantly stirred to permeate it with the alcohol. The stop-cock H is then slightly opened to allow the fluid to run off. The alcohol and original solvent are finally separated by distillation.

The apparatus above described, though very effective, is somewhat obsolete, since for the preparation of chemical products in general and especially of chlorine, clay vessels are now made in

numerous factories which are cheaper and just as effective as wooden vats lined with lead.

As has been stated, rubber bleached in the manner above described is of a brownish-yellow color, and should be immediately worked, as it is quite soft when it comes from the bleaching apparatus, and can be easily compounded with admixtures.

According to an American process 2 lbs. of rubber are dissolved in a suitable vessel in 4 lbs. of chloroform. The solution is allowed to clear by settling, and ammonia is then introduced to saturation. When the rubber is completely bleached, which is ascertained by frequently examining a sample, the solution is washed with hot water in a vat provided with a stirring apparatus, to remove all traces of ammonia and chloroform. The separated rubber forms a spongy mass which is squeezed, pressed, dried and mixed with sufficient chloroform to form a thick dough. This dough is intimately compounded with enough phosphate of lime or carbonate of zinc to form a mass having the appearance of damp flour, which is pressed in hot moulds. The articles taken from the moulds may be further worked in the turning lathe. By adding suitable coloring matters with the phosphate of lime, imitations of coral, enamel, etc., can be prepared.

The simplest method of bleaching rubber for preparing artificial ivory is to treat it in the usual manner, and to form thin bands from it by passing

it through the rolls. These are allowed to fall into a roomy vat, provided with a cover, and containing water saturated with chlorine.

By using the rubber in the form of thin bands, the bleaching process goes on quite rapidly, and when complete, it is only necessary to wash the mass several times in hot water to free it from the adhering chlorine. It is advisable to add a small quantity of sodium hyposulphite (1 per cent. of the salt is sufficient) to the first washing water, as this salt has the effect of removing every trace of chlorine which may still be present. If any of the chlorine were to remain it would exert an injurious effect afterwards when the material has to be worked in machines constructed of metal.

The best plan is to subject the bleached mass to further treatment immediately after it has been washed, as it is then very plastic. But if it is not desired, nor possible to use the mass at once, it is advisable to moisten it with some carbon disulphide or benzene and to let it remain for some time in a hermetically closed vessel. A small quantity of the solvent will cause the mass to swell up somewhat, and it can then be worked with greater ease.

The next operation for preparing artificial ivory is to incorporate several substances with the plastic mass. Either whiting, oxide of zinc or white lead is used for producing a white material. Artificially prepared sulphate of baryta (the *blanc* or *fix* permanent white used as a coloring substance by the manufacturers of wall papers) is also a very

suitable material for the purpose. Articles colored by pigments containing white lead, lose their white color in time and turn gray.

The colored masses are worked in different ways, either direct or indirect. If the direct method is chosen, the artificial ivory is immediately pressed into hot moulds, but sharp impressions can only be obtained by using a very high pressure. Many elegant articles can be prepared in an inexpensive manner by this method, provided it is not absolutely necessary that the substance should be entirely homogeneous. Knife handles, buttons, etc., may be prepared by direct pressing.

For solid, but at the same time non-elastic articles, it is best to use the indirect method, that is to say, the mass is formed into cubes, and the articles are shaped from them by the lathe, etc. Therefore the preparation of artificial ivory must be regulated by the use intended. For instance, the material for billiard balls should undergo less pressure than that for making thin sheets.

The greater part of the numerous receipts given for preparing artificial ivory, are of no special value, as its quality depends so much upon the rubber used, the duration of the chlorine treatment, etc. According to many of the receipts, masses are made resembling vulcanite, by using sulphur and gutta-percha in addition to rubber, and heating them to 302° to 320° F.

Jacobsen gives an American receipt, according to which a mass for artificial ivory consists of the following substances:

	Parts.
Rubber	100
Sulphur	45
Gutta-percha	10

The mass is heated to 314.6° F.

While it has been considered of interest, for the sake of completeness, to give a description of the manufacture of artificial ivory from rubber, with the present high prices of the latter material the product is not remunerative, especially as at the best it is an imitation, which has many defects. Besides, masses are now prepared from celluloid, which as regards their properties, resemble more closely ivory than the best rubber compositions, and are much cheaper.

CHAPTER VI.

MANUFACTURE OF ARTICLES FROM SOFT RUBBER.

WITH the exception of waterproof stuffs, the manufacture of rubber articles depends upon plastic manipulation, the greater portion of the work being done by hand. Actual machinery is but little used, but, on the other hand, a great variety of moulds and presses are employed.

The best known articles in general use made from fine cut sheets are: Nipples and fittings for milk bottles, tobacco pouches, tubes for chemical laboratories, and the many articles for chirurgical and technical purposes, for which no other rubber material is as suitable. The manufacture of these articles depends on hand work, and is very simple, because the cut surfaces of the sheets produced with a knife, die or scissors when pressed together adhere immediately, this being still more the case if a thin coat of benzine or of thin rubber solution be first applied to them by means of a small brush. Hence it is only necessary to cut out according to a pattern with scissors or a knife the several parts of the articles to be manufactured, or when large quantities are to be produced, for instance, nipples, to die them out and then put them together either by hand or over a mould. In order to make a

better joint, the seams are either smoothed with a paper folder or hammered with a light hammer having a rounded face, over a mandrel or anvil with a rounded surface. Hollow articles—balloons, tubes, etc.—are dusted inside with talc to prevent the sides from sticking together. The vulcanization of these articles is also a very simple operation.

Rubber toys. The manufacture of these articles has become quite an important branch of the rubber industry, as on account of their indestructibility and softness they are especially adapted for children's use. Human figures, for instance, are made from vulcanized rubber by pressing in metallic moulds, so that the figure is obtained in two halves, each a few millimeters thick. These are joined together by rubber solution, so that they form a hollow body, and are then heated. As the enclosed air expands during the heating process, and would cause the figure to burst, a small hole is made in some part of the latter to allow the air to escape. The hole is later on closed by a small rubber plug.

Such figures are also made from sulphurized sheets with the use of a type-metal mould. The sheets are cut according to patterns with a pair of scissors in such a manner that the cut surfaces are slightly sloping, which facilitates their adhesion. Before entirely closing the figure, a small quantity of water, ammonium carbonate, or another substance which at the temperature of heating is converted into steam, is poured in. The completed figure is then brought into the mould. The steam evolved exerts

a pressure upon the rubber, and presses it into all the depressions of the mould, filling the latter completely. After vulcanizing, a small hole is made in the figure to admit air, as otherwise the figure would collapse in consequence of the condensation of the steam and the formation of a vacuum.

Rubber balls are made in a similar manner. Segments of a sphere are first cut according to pattern from rubber sheet, and then joined together to a ball in a plaster of Paris mould. In order to make the balls very elastic they are, after vulcanizing, filled with compressed air. When taken from the moulds, the balls are perforated with a fine hollow needle, and air is forced in through the latter by means of a small compression pump until a pressure of two or three atmospheres is indicated. The needle is then withdrawn, and the hole quickly closed with sulphurized rubber, which is vulcanized by holding a hot iron close to it.

For larger balls with thicker walls, a higher pressure may be used, and it is advisable to fill the balls on a cold day in the open air, since the air on becoming warm acquires greater tension.

The so-called velours, or velvet balls, are made from gray rubber mass, then coated with a solution of pure Para rubber, and before the latter is entirely dry provided with velours covering. From balls thus treated the air does not escape, and they retain their spherical shape.

Hollow articles of any desired shape can also be prepared by using the rubber dough, the prepara-

tion of which has been described in a previous chapter. The process is nearly the same as that employed in moulding hollow articles from plaster of Paris. The moulds used for the purpose may be made of metal, wood, or plaster of Paris, but when of the last two materials they must be coated, before use, with linseed oil varnish, the coating being repeated until the moulds absorb no more varnish.

Moulds consisting of more pieces than one are put together in the same manner as those used for moulding articles from plaster of Paris, and the rubber dough is then poured into the hollow part. In doing this the mould is swung to and fro in such a manner that the interior wall is covered with the thick fluid mass, and then the excess of dough is allowed to run off. But, with some experience, the latter is not necessary, as a skilled workman can estimate the exact quantity of dough required for a mould of a certain size.

To accelerate the evaporation of the solvent from the dough, it is advisable to fit a pipe into the mould through which air is blown into the interior. By this the vapors of the solvent are quickly carried off. Finally, the mould is placed in a warm room to dry.

A suitable quantity of finely powdered sulphur or other vulcanizing agent may be mixed with the dough before it is formed into articles, and, if this has been done, it is only necessary to place the articles which remain in the mould in the heater to vulcanize them. If pure rubber dough has been used, they can be vulcanized by a simple process.

For this purpose they are dusted with finely powdered sulphur, and some of it is also blown into the interior of them. They are then heated in the usual manner; or they are vulcanized by using chloride of sulphur.

Small solid balls of vulcanized rubber are required for sewing machines. These are prepared from sulphurized rubber and heated. A peculiar process is used in many factories for manufacturing them from pure rubber. A block of the latter is pressed against a grater, which revolves as quickly as possible, and by this is cut into exceedingly fine shavings which can easily be balled together.

Balls are formed from these shavings with the hand. They are tightly pressed in metal moulds, then brought into a somewhat smaller mould and in this subjected in the cold to as strong a pressure as possible. They are very compact, and must be heated to 104° F. to restore to them their elasticity. Balls manufactured in this manner are especially adapted for bearers under powerful stamping presses, as they drive the stamp back with great force.

The small toy baloons belong also to the specialties of the rubber industry. Very small balloons are made from clear rubber solution. A glass balloon serves as a mould. A certain quantity of solution is poured into this and distributed over the entire inner surface by swinging the mould to and fro, and the excess of solution is then allowed to run off. When nothing more drains off the

mould is replaced with the neck uppermost and air is blown in to accelerate the evaporation of the solvent.

To detach the balloon from the glass, to which it adheres quite tenaciously, the lower edge of it is carefully loosened from the glass and then air blown in between the film and the glass. The thin film, of which the balloon consists, becomes entirely detached from the glass and can be removed in the form of a bag.

The rubber sheets prepared upon glass plates, as described in a former chapter, may be used for somewhat larger balloons, such as are employed at meteorological stations for ascertaining the direction of the wind. As most of these balloons have a volume of a few quarts only, they are generally filled with illuminating gas and then closed.

Printing rolls for use in dye work, etc., are prepared with the simultaneous use of pressure and heat as follows: A tube made of a sheet of sulphurized rubber mass is tightly drawn over the roll of which a cast is to be taken, and firmly wrapped around with cotton cloth so that all depressions are filled up. The entire mass is then vulcanized, and after heating the tube is withdrawn and turned inside out.

Letellier and Verstraat make the rubber jacket of the pressure rolls of cloth printing machines of two layers. The metal drum is first wrapped round, 2 millimeters thick, with cotton. Upon this is brought a layer of hard black rubber of 1.6

specific gravity, and this is coated with softer rubber of 1.3 specific gravity. The total thickness of both layers is 20 millimeters, and the upper layer is accurately turned for printing, and polished with emery.

Preparation of rubber threads. The manufacture of threads forms an important branch of the rubber industry, since on account of their elasticity and tenacity, they are extensively used in the fabrication of elastic tissues. How extensive this use is may be understood from the fact that large factories are entirely devoted to the manufacture of materials from which the elastic webbing for shoes is made.

Rubber threads may be prepared according to various methods, but their elasticity and toughness depends on the raw material used. It may here be remarked that rubber which has been shredded, masticated, and then brought into a compact mass by rolling, does not possess the solidity and elasticity of the raw material, and, of course, threads manufactured from the former are of a poorer quality than those prepared from the latter.

Square cords from crude rubber. The best quality of rubber in the form of bottles, with the thickest sides and of the most regular shapes, should be selected for making such cords. The necks of the bottles are cut off, and the bowl or body is bisected by a cross-cut. The pieces are then examined, and only those having an entirely uniform appearance are selected. Pieces showing large hollow spaces, or an indication of the presence of foreign bodies, must be rejected, they being unsuitable for the purpose.

The next step is to convert the pieces obtained by cutting up the bottles into smooth, even sheets. This is effected by softening the pieces by continued boiling in water, and then placing them between level iron plates in a powerful press and subjecting them to strong pressure for a few weeks, the press being from time to time tightened. As a low temperature helps to make the rubber more compact, it is advisable to carry on the work of cutting threads in winter, and to place the presses in the open air.

The sheets when taken from the press should be perfectly smooth and of uniform thickness. They are then brought to the cutting machine. This consists of a shaft upon which the sheet is fixed vertically by means of sharp points. The shaft revolves around its axis, progressing forward at the same time. A knife, moving quickly to and fro, cuts a spiral band from the sheet, the thickness of the band depending on the greater or smaller velocity with which the sheet approaches the knife. A stream of water falls steadily upon the knife to prevent the rubber from sticking to it. The long band obtained by the operation is then cut into square cords. In many factories the neck and bottom of the bottles are cut off, and the remainder softened in boiling water, then drawn over a wooden mandrel covered with a thin layer of rubber. This mandrel while revolving is raised a certain distance and moves against a knife, placed vertically, which cuts a spiral band from the rubber. This is a simpler manner of obtaining a band of crude rubber,

but the cords cut from it are not quite so solid as those manufactured from the pressed halves of the bottles.

The bands, obtained by either of these methods, are now cut into cords or threads by machines, as they do the work with much more regularity than is possible by hand, and save a great deal of time.

The simplest manner of cutting the bands into threads is between two steel rolls, in the circumferences of which are grooves as broad as the threads to be cut, and so arranged that the upper roll covers every groove in the lower one. The sheet of rubber passing through between these rolls is cut into a corresponding number of equally wide threads which are wound upon reels. The dividing of the sheet of rubber by this machine must be called *crushing* rather than cutting, and, if the threads are to be cut smooth, it is necessary that the edges of the grooves should be extremely sharp.

More complicated, but more effective, is the thread-cutting machine, consisting of a horizontal shaft with circular knives, separated according to the width of the threads to be cut. Above this shaft, holding the knives, is placed a roll with narrow grooves, into which the knives penetrate slightly.

A pair of smooth rolls grasp the sheet to be cut into threads and carry it through between the grooved roll and the knives, which revolve with as much velocity as possible, and cut the sheet into a corresponding number of threads. They are then

passed through between glass rods and wound upon reels.

Cutting square cords from prepared rubber. Although threads cut directly from the raw material are toughest, their use is limited to certain purposes, as they cannot be obtained of any considerable length, and have the further disadvantage of not being vulcanized. Hence for the manufacture of long threads or of threads from vulcanized rubber, prepared rubber, either by itself or mixed with sulphur for vulcanizing, has to be used.

The sheet from which long vulcanized threads are to be cut is first vulcanized and then cut.

At the present time long threads of ordinary or vulcanized rubber are generally prepared from tubing which is divided by a spiral cut. The tubing to be cut is fastened upon a wooden mandrel, which fits exactly into the bore of the tube, and this is fastened to a metal screw which gradually moves forward. A knife moving quickly to and fro cuts a spiral strip from the tube, the width of the strip depending on the height of the screw-thread. Rectangular threads are obtained by using a screw with threads of less height than the thickness of the walls of the tubing.

The machines for cutting threads from tubing have recently been much improved, and threads of any desired thickness can now be prepared by using but one screw.

But in whatever manner the threads may be manufactured, it is of the utmost importance that

the greatest care should be used in winding them upon reels to prevent the freshly cut threads from sticking together.

Round rubber threads. For certain purposes, round threads are required. They can, however, be manufactured only from rubber which has been changed into a plastic mass by treating it with proper solvents. This plastic rubber is then pressed through a metal plate provided with circular holes.

According to Aubert and Gerard's process the purified rubber is cut up into small pieces and brought in contact with carbon disulphide, alcohol, fusel oil, or wood spirit. Neither of these dissolves the rubber, but they disintegrate its particles, so that they can be easily manipulated into a uniform paste or dough.

The following is a very suitable mixture for this purpose:

	Parts.
Rubber	100
Carbon disulphide	100
Alcohol, 85 per cent. strong	5

The substances are placed in a hermetically closed metallic vessel, and allowed to stand for from 15 to 18 hours. The mass is then pressed through a wire netting with close meshes, which retains the particles not entirely swelled up. The plastic mass, which should be of the consistency of thick paste, is then brought into the moulding apparatus.

This consists of a cylinder in the bottom of which

are fitted a number of cone-shaped tubes the bore which corresponds to the diameter of the threads be formed. A piston, which should fit as accurately as possible in the cylinder, slowly forces the plastic mass out of the above-mentioned tubes.

The threads thus formed, on coming from the tubes, first reach an endless band of cotton velvet about 13 feet long. While they are carried away by this band they lose a considerable part of the carbon disulphide by evaporation, and obtain thereby a certain degree of solidity. From the velvet band they pass to a second endless band of fine wire gauze which is kept in a shaking motion, while finely powdered talc falls constantly upon the threads. By the shaking motion of the band, the threads are covered everywhere with the talc powder, which prevents them from sticking together.

To entirely evaporate the carbon disulphide which may still adhere to them, *Aubert* and *Gerard* use a system of endless linen bands consisting of five bands, each about 52 feet long. They are arranged one above the other and move in opposite directions so that the threads run to and fro.

About ten minutes are required for them to run over all the endless bands, and during this time they lose sufficient of the carbon disulphide that they can be wound upon reels without sticking together.

They are wound in the same manner as the loose cotton bands in cotton mills. Funnels stand over vertical tin boxes which all revolve around their

axes at the same velocity. The thread glides through the funnels into the boxes and is wound up in it to a spiral.

When the cylinder from which the plastic rubber is forced is nearly empty, it is filled up again, and in this manner threads of any desired length can be manufactured. If threads of a specific diameter are to be prepared, the fact must be taken into consideration that the diameter of the threads decreases considerably in drying. A thread pressed through a tube having a diameter of 0.039 inch, when dry will have a diameter of only 0.028 inch.

Only threads having at least the diameter mentioned above can be prepared by pressing. If holes of a smaller diameter than 0.039 inch are used, the plastic mass breaks constantly and the work cannot be carried on without interruption. A peculiar physical behavior of rubber is taken advantage of for preparing still thinner threads.

Namely, if a thread of rubber is stretched lengthwise and simultaneously exposed to a temperature of 239° F., it will retain the length to which it has been stretched even after the tension ceases. If the thread which has been dried in this manner is again drawn out lengthwise, and again heated to 239° F., it remains stretched, and by several times repeating this operation threads of a much smaller diameter can be obtained than is possible by cutting or pressing.

Rubber hose. This forms a very important commercial article, as on account of its pliability and

resistance to chemical agents, it is used in many industries. The demands made in practicc on rubber hose are manifold, and frequently it is not easy to come up to them.

Hose or tubing for chemists' use and for conducting illuminating gas should be as thin and pliable as possible, and at the same time impermeable to gas. Hose for conducting compressed air, an indispensable component of rock drills, should be able to withstand a pressure of several atmospheres.

It is absolutely necessary that hose which shall answer all reasonable demands should not kink when used in short bends. Such kinking is very annoying, as it obstructs the flow of the fluid or gas contained in the hose until it is again straightened out, and subjects the manufacturer to the charge of furnishing unserviceable goods. This defect is found chiefly in hose the walls of which are too thin, and can be avoided by maintaining due proportion between the diameter and the walls of the hose.

Manufacture of ordinary rubber hose. It is now customary to manufacture hose from vulcanized rubber, it being more servicable than that from ordinary rubber, which soon becomes brittle and full of cracks, especially when frequently exposed to changes of temperature.

A plastic mass, obtained by mechanically treating a compound of rubber and sulphur, is used for making hose. The mass is first rolled into sheets of a thickness corresponding with that of the walls

of the hose which is to be prepared, the interior diameter of the latter being determined by an iron core over which the plastic mass is shaped.

Cores of round smooth wire are generally used for hose of a small diameter, but for hose of a larger diameter wooden cores are preferred, since iron cores, on account of their weight, are difficult to handle. But the wooden cores must be perfectly cylindrical, and it is advisable to saturate them, before use, with hot linseed oil.

For manufacturing short tubing the plastic mass is cut into bands somewhat wider than the circumference of the core. These bands are then placed around the core and joined together by gentle pressure. Finally the core with its envelope of rubber is rolled upon a smooth table to give the tubing a perfectly cylindrical form. It is then wrapped in a linen cloth which remains around it during vulcanizing. When taken from the heater, the core is withdrawn, and the linen cloth removed from the tubing, which is now finished.

If hose of greater length or larger diameter is to be manufactured, the rubber is generally used in the form of a band, which is laid in spirals around the core in such a manner that the edges slightly overlap. By pressing with the fingers and rolling upon the table, they are joined together to a hose which is treated in the same manner as has been described.

But rubber alone is not sufficient where the hose has to bear a great pressure, and it becomes neces-

sary to strengthen it by intermediate layers of tissues and spirals. Of course this increases the solidity, but decreases the flexibility of the hose to a great degree.

Rubber hose with intermediate layers or stiffeners. Hose with an intermediate layer of tissue is prepared by first forming a thin hose from plastic compound. A piece of the tissue is placed over this, but this must be wide enough to allow the ends to lap over. The tissue before it is laid upon the hose is brushed over with a solution of rubber, and in placing it in position, great care must be observed to prevent the formation of air bubbles, as on the places where such are present, the rubber and tissue do not unite, and experience has shown that, when the hose is subjected to a high pressure, it bursts first at those defective places.

When the tissue has been applied, it is covered with a second layer of plastic compound, so that it is entirely inclosed and can only be seen on the cross-section.

For hose with layers of wire, the latter is used in the form of spirals, which are wound over the hose formed on the core, and then covered in the usual manner with a second layer of rubber.

Small hose can also be manufactured with the machine used for pressing threads. But in this case the cylindrical holes through which the plastic rubber is forced are replaced by openings in which cores of suitable size are inserted. The latter are hollow, and are connected with a vessel containing

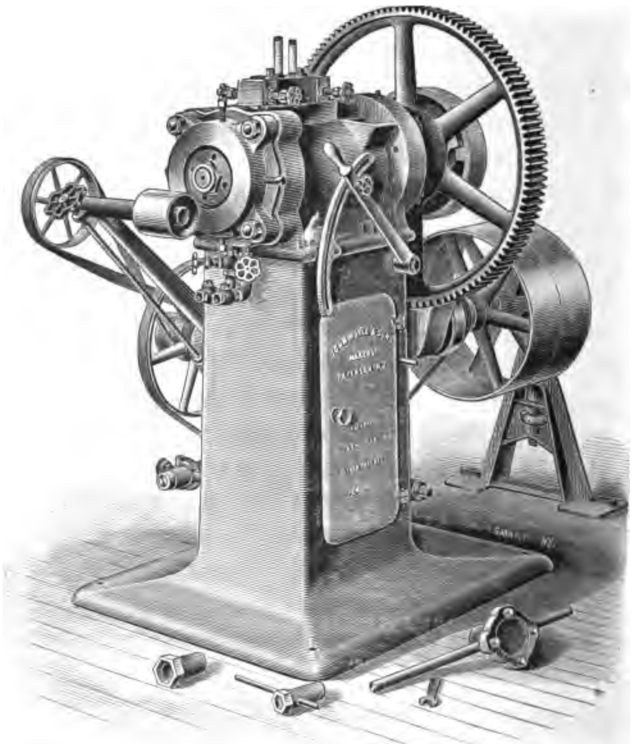
water. The small hose as it comes from the cylinder is closed by pressing the ends together, and filled with water as quickly as it is formed. This is absolutely necessary, as the hose would collapse if this precaution were neglected, and the sides stick together. The subsequent treatment of the hose is exactly the same as that of the threads. When it is finished, it is opened and the water allowed to escape.

Tubing machines of various sizes are manufactured by John Royle and Sons, of Paterson, N. J. Fig. 11 shows their tubing machine No. 2, which is well adapted to making the larger sizes of tubing, such as fire-hose lining, etc., and for making various shapes of a greater size than can be conveniently handled in smaller machines, which are more suitable for syringe and flower tubing and various small-sized druggists' and stationers' sundries.

The most important feature of a tubing machine is the cylinder, upon the construction of which the harmonious working of the various parts depends, as it is in the cylinder that the heat necessary for the proper working of the compound is applied. Nearly all the different tubing compounds are highly sensitive to the action of heat, and require to be subjected to various degrees of temperature at different points while passing through the machine. To produce the heat in sufficient quantities, and under perfect control as to direction and extent, has been the main object aimed at in the construction of the cylinder in the Royle machines. Thus when working india rubber or other similar material, it

is necessary to heat the head and cylinder so as to soften the mass and facilitate its delivery through the die, and it is also essential that the degree of heat applied should be readily controllable in order

FIG. 11.



that the consistency of the material may be so regulated that it will become sufficiently plastic to mold readily, and at the same time retain the form given to it by the die. To effect this result it may be

necessary, in some cases, to heat both the cylinder and the head, while in others it may be necessary to heat only the cylinder and cool the head, or to cool both cylinder and head. To provide for all contingencies, both head and cylinder are jacketed, and equipped with a steam-chest having separate compartments for steam and hot water. Suitable passages issue from these compartments for conveying the steam and water directly to the cylinder and head, and an arrangement of valves is provided, by means of which the flow of water and steam can be regulated, and any desired temperature maintained. The passages and valves are arranged as integral parts of the machine, and no external pipes or connections are needed, except the main supply and discharge pipes for conducting the heating and cooling fluids to and from the valve-chest. The bore of the cylinder has a suitable lining, so arranged that, in the event of wear, it can be replaced at a nominal cost.

The *head* for holding the dies, etc., for giving the desired form to the material as it issues from the machine, is so arranged that dies, cores and core-bridge can be readily removed from the front of the machine without disturbing it. It can, however, be readily detached, when desired, by simply loosening the nuts on the stud-bolts by which it is attached to the cylinder.

The *dies* which give form to the outside of the compound as it issues from the machine are made in two styles, thimble and thread, and are held in

place in the machine by means of holders which screw into the head from the front. The thimble dies are fitted into the bore of the holder from the back and are held in place by a rim of metal, while the threaded dies are hexagonal-shaped on the outside and have a threaded stem which screws into the holder from the front. The holders for both styles of dies are graduated in size, so that each holder will accommodate a series of dies of different sizes. Thus, with very few holders, a large assortment of dies can be used.

The *cores* used in making tubing are secured between the head and cylinder by a core bridge. As the core must, of necessity, be concentric with the die in order to insure uniform thickness in the tubing, an adjusting device is provided, by means of which the position of the core can be easily regulated. This device consists of four screws placed at regular intervals around the core bridge and bearing on it at different points of its circumference. By simply tightening or loosening these screws, the core-bridge and core can be readily secured in any desired position and perfect alignment with the die maintained. This provision for maintaining absolute relative accuracy between the die and the core is an important feature of the machine. The method of adjusting from the core-bridge instead of from the core itself, together with the axial adjustment of both die and core, renders it possible to maintain perfect alignment without deflecting the core or impeding the flow of the compound.

The rubber or other raw material is fed into the cylinder through an opening at the back, and is then carried along and forced through the die by a powerful Archimedean screw or stock-worm which extends along nearly the entire length of the cylinder, and is turned by powerful worm or spur gearing, as the case may be. This stock-worm is made of steel, and is very durable; the walls of the threads being of sufficient thickness to withstand the wear and tear of constant use for an unusually long time. As it is sometimes desirable to change the worm in use for one of different capacity, these machines are so arranged that the stock-worm in use can be removed and another substituted without difficulty.

A valuable feature is the carrying belt, or apron, for conveying the tubing or other product from the die, without stretching or distortion. This apron extends from immediately beneath the die to a revolving pan, or other appropriate receptacle, placed on the floor at a suitable distance from the machine. It is supported by an adjustable arm extending from the machine, and the driving mechanism can be so adjusted as to make the delivery of the tubing from the die and the movement of the apron synchronous. This receiving apparatus is a distinctive feature of the Royle machines, and adds materially to the quality of the finished product, as it not only prevents distortion and wrinkling, but also allows the soft and impressible gum sufficient time to harden somewhat before being delivered into the pan. This

is an advantage that practical makers of rubber goods will readily understand.

Rubber sponge or moss rubber. This peculiar product was first manufactured by P. W. Cow, Hill & Co. The mode of manufacture is still kept secret, but is said to consist in repeated vulcanization, softening and pouring into moulds, the resulting product being a sort of sponge more or less cellular and porous like a sponge, and possessing the property of absorbing water and allowing it to escape when pressed. Dr. Wiederhold is of the opinion that rubber sponge is prepared as follows: A solution of rubber in carbon disulphide, or chloroform, or benzene, is quickly heated, whereby the last remnants of the solvent distend the mass, which has become very viscous, and thus imitate the cellular structure of sponge.

According to other experiments, rubber sponge may be produced as follows: A tall tin vessel of prismatic shape is filled a few centimeters deep with rubber solution and the latter heated to above the boiling-point of the solvent used in the preparation of the solution. In consequence of the evaporation of the solvent, the mass becomes more and more viscous, and as the steam bubbles force their way through it with constantly increasing difficulty, the final result is a very porous and cellular product. By using rubber dough and heating very slowly, sponge with very fine pores is obtained which as regards softness, by far surpasses the finest bathing sponge. The finished product is

vulcanized by plunging it into a solution of chloride of sulphur, and may be further provided with a suitable base of hard rubber so as to make it handy for use.

However, the disagreeable odor of these sponges, which is perhaps more perceptible on account of their porous nature than is the case with other vulcanized rubber articles, prevents their general use. This odor can, however, to some extent, be overcome by the use of animal charcoal. The sponges are simply wrapped up in tissue paper and placed in a vessel filled with powdered animal charcoal. In a few weeks, especially if the vessel be put in a warm place, the sponges will have lost nearly all odor, and the last traces of it may be removed by washing.

These rubber sponges have been highly recommended for washing horses, they having the advantage over the curry-comb of not injuring the skin of the animal or tearing out hair, while at the same time the dust is completely removed and a beautiful lustre is imparted to the hair. In the form of brushes, provided with a hard rubber back, they have been recommended for cleaning clothes, cloth, ribbons, fine tissues, such as velvet, etc.

Rubber shoes. In the course of time this article has passed through a peculiar process of development. The first so-called gum shoes consisted of a single piece of rubber and were made in the same manner as the bottles of crude rubber. Clay moulds in the shape of a last were coated with the

latex and dried over a fire. The congealed coating was then drawn from the last and formed the shoe. Shoes prepared in this manner were very durable, but ugly, and had the further defect of enclosing the feet tightly and producing in them in a short time a feeling of almost unbearable heat. Later on shoes were made by cementing together pieces of rubber, but these had the defect of soon losing their elasticity. Goodyear was the first to make shoes of vulcanized rubber, and the extent of the present manufacture may be judged from the fact that a single factory turns out 3000 pairs a day. It may, however, be mentioned here that under the name of rubber shoes, products are brought into the market which do not deserve the name, as no rubber whatever is used in their manufacture, but only elastic varnish colored black.

Genuine rubber shoes are made as follows: A tricot-like tissue is coated by passing through between rolls with a thin layer of sulphurized rubber colored black with lamp-black. The separate parts which are to form the shoe are cut from the sheet thus prepared, the sole being cut from a somewhat thicker sheet, and cemented together with rubber solution over hollow iron lasts. They are then coated with asphalt lacquer and vulcanized over the last.

Bicycle tires. Pneumatic tires for bicycles, etc., may be divided into two classes: Single-tube tires, in which an endless tube is made air-tight and sufficiently strong to resist the air pressure, and

compound tires consisting of two parts—an inner air tube and an outer cover.

Single tube tires are formed of alternate layers of more or less pure rubber and strong cloth or canvas. The interior is made of pure or nearly pure rubber, the object of its introduction being to form an absolutely impervious surface to the passage of air. The strength of this inner layer is practically nothing, its principal office being to fill the interstices found in the material surrounding it, and which possesses the necessary strength to resist the inflation by the air.

Mr. Henry Sturmey divides compound tires into five classes according to the mode of adjustment of the outer cover to the rim, viz: Solutioned tires, wired tires, interlocking and inflation-held tires, laced tires and band-held tires. It would lead too far to describe all these classes of tires, and hence only a description of the original "Dunlop" tire, with which originated the principle of air tubes for cycles, will be given, and of the Morgan and Wright tire, both of which belong to the solutioned type of tires. In the Dunlop tire the outer cover consists of a thick tread of rubber solutioned to a canvas strip. A complete woven tube of canvas encircles the air tube and is solutioned to the rim, which is previously wrapped round by a canvas strip, while the flaps of the outer cover are solutioned to the inner surface of the rim, one flap being lapped over the other, the side being split to pass the spokes. A strip of canvas solutioned over the flaps, makes a neat finish.

In the Morgan and Wright type, the air-tube is butt-ended, or rather scarf-ended, the two ends overlapping each other about eight or ten inches. The outer covers form practically a tube slit for a few inches along its under side. This opening serves for the insertion of the air-tube, and is laced up when the air-tube is in place. When partially inflated the tire is cemented on the rim.

Manufacture of water-proof tissues. There are two kinds of water-proof tissues, known as double textures and single textures. The first consist of two layers of the same or different stuffs cemented together by a thin layer of rubber. Single textures consist of a single tissue which is coated with rubber either only on one side (single face) or on both sides (double face).

Rubber was first used in the manufacture of water-proof tissues by Charles Macintosh, and the material was called by the name of the inventor. It possessed the advantage of being very durable, but on the other hand had the disadvantage of being very weighty, thick and expensive. It was prepared by placing a thin sheet of rubber between two tissues and passing the whole through between heated rolls.

By this manipulation the rubber was so strongly heated that it became soft, and was pressed into the meshes of the fabrics, cementing them firmly together. Many experiments were made to improve Macintosh's process by decreasing the weight and thickness of the materials, but this has only been

accomplished since the introduction of the new process of working rubber, which renders possible the preparation of very thin sheets.

Dumas suggested the preparation of very thin sheets by allowing a solution of rubber in ether to run down over heated rolls. The ether would thereby evaporate and the soft thin sheet remaining behind, which could readily be detached from the polished rolls, was to be spread upon the tissue. The latter was to be covered with a second layer of tissue and the whole cemented together by rolling.

It is absolutely necessary that the layer of rubber should be as thin as possible, if it is desired to prepare an article which will answer all reasonable demands. So much progress has been made in cutting cylinders of rubber into thin sheets, that they can be furnished not much thicker than a sheet of writing paper. A successful attempt has been made to coat only one side of a tissue with such thin sheets, but this unfortunately has the disadvantage of making the material heavy, and of being rather expensive. A decided improvement in the manufacture of water-proof materials has only been made since the process of obtaining rubber in a very soft form by mechanical treatment became known, but the greatest perfection in the manufacture of this important article has only been reached since the introduction of vulcanized rubber.

The first improvement in Mackintosh's process consisted in the use of but one layer of tissue, and by making the sheet of rubber as thin as possible,

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the bulk of the material was considerably decreased. The manner of manufacturing these water-proof fabrics was very simple, and was carried on as follows:

The crude rubber was first converted into as homogeneous a mass as possible by passing it through between rolls, and was finally rolled into very thin sheets. When the latter are taken from the rolls they are quite sticky, and this is made use of for cementing them to the tissue, which is accomplished by placing the fabric upon the sheet of rubber and passing the whole through between rolls.

Before entering upon the discussion of the more modern methods of making water-proof fabrics, a few words may be said about the character of the tissues to be employed. The material may be either silk, wool or cotton; as the tissue is simply the bearer of the substance which renders it water-proof, either loosely or closely woven fabrics may be used. In the first case a considerable quantity of rubber is required for water-proofing, and in the latter only a small quantity.

Most manufacturers have found it best to use closely woven fabrics for water-proof tissues, as these require less rubber and besides have the advantage of being firmer. Therefore strong cotton goods are generally used at the present time for finer articles, such as water-proof coats and cloaks. The principal requisite of such materials is that they should be as even and smooth as possible, since

even the smallest knot in the tissue exerts an injurious effect upon the quality of the goods to be manufactured.

At the present time, as has been mentioned, very thin coatings of rubber can be prepared. If there should be knots in the tissue they would, of course, be covered with rubber and the fabric would seem to be of excellent quality as long as it is not used. But, if a garment made of such material is used for a short time, the rubber will commence to peel off wherever the knots are.

Fabrics of cloth and vulcanized rubber can be prepared by rolling the soft compound of rubber and sulphur into very thin sheets and passing them together with the cloth through between heated rolls. The object of heated rolls is to force the rubber compound firmly into the meshes of the tissue, and, if the proper temperature be used, at the same time to vulcanize the rubber.

One pair of rolls, heated to the temperature required for vulcanizing, may suffice for the work, but very careful and skilled workmen are then required. Experience has shown that it is much better to use two pairs of rolls, the first pair of which is heated at the utmost to 248° F., while the second is heated to the temperature required for vulcanizing the rubber compound. Finally, the finished fabric is rolled upon cylinders as soon as it has become sufficiently cooled off, and should be further worked as soon as possible.

It is, however, difficult to obtain uniform pro-

ducts in this manner, and experiments have, therefore, been made to use vulcanized rubber. But as this, as is well known, cannot be cemented together, and will not combine with the tissues by pressing, it is necessary to have recourse to certain manipulations to obtain the desired object.

According to the method recommended by Johnson, very thin sheets of vulcanized rubber are prepared, and these partly desulphurized by boiling for some time in caustic soda. After they have been boiled, they are first washed in water containing some hydrochloric acid (to remove the last traces of the alkali), next in pure water, and then dried.

The sheets, thus prepared, are roughened by passing them over a roll covered with emery paper and revolving with great speed (800 to 900 revolutions a minute). The object of this is to facilitate the union of the rubber with the tissue.

The sheet is then coated with a rubber solution and placed upon the tissue and both together are passed through between the rolls in order to cement them together.

The articles manufactured in this manner are of excellent quality, but, on account of the process being so very complicated, rather expensive. Since the method of completely dissolving rubber has become known, solutions, or a paste of it, are almost exclusively used for the manufacture of water-proof tissues, and these are generally only coated on one side.

Although the work seems to be very simple when solutions are used, nevertheless many difficulties present themselves in the execution of the operation. Frequently the very volatile oils, which are obtained by distilling coal tar—light coal-tar oil or naphtha—are used as solvents on account of their cheapness. It is true that these solvents volatilize very quickly, but they are mostly always mixed with small quantities of less volatile products, which remain behind after the volatilization of the lighter oils, and the odor of which adheres to the rubber so that it is perceptible for years. This odor —agreeable to no one—is so repulsive to some persons that they will not use a garment manufactured from such tissue.

A further evil of using pure rubber solutions is that the layer of rubber, which is left behind, remains sticky for some time, and, for this reason, a garment, prepared from it, cannot be folded up, as the surfaces would stick together so tight that the folds could not be separated.

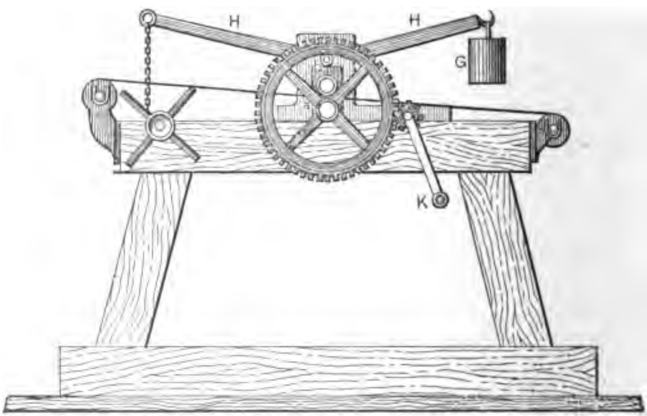
All these evils are now removed by using a rubber paste which also contains the substance required for vulcanization, and by subjecting the freshly coated tissue to the heating process.

Such solutions, or more correctly speaking, such compounds, used for this purpose are at once mixed with the quantity of sulphur required for vulcanization. The simplest manner of doing this is to saturate the carbon disulphide used for dissolving the rubber with sulphur, or by working very finely

powdered sulphur into the mass. The principal requisite for a correct execution of the work is, that the mass should be entirely homogeneous, a property which can be imparted to it by a suitable mechanical treatment, as has been explained in a previous chapter.

For spreading the rubber compound upon the tissue as uniformly as possible and to cement both together, a special machine is required. It makes

FIG. 12.



very little difference which of the various makes of machine is used, as they all answer the purpose for which they are intended, a thoroughly experienced workman being the principal requisite for the work.

A spreader well adapted for all purposes is shown in Fig. 12.

Two rolls of small diameter, generally 7 to 7¾ inches, rest in brasses upon a suitable frame. The

lower roll is made to revolve and is set in motion by cog-wheels and the crank *K*, with which they are connected. The upper roll has square arbors which fit into the brasses, and therefore it does not revolve.

The object of the upper roll is to regulate the thickness of the solution which is to be spread upon the tissue, and for this purpose is provided with a peculiar mechanism. Two levers, *H*, *H*, having their fulcrum at *b*, and loaded with weights *G*, press with a certain force the upper roller against the lower one, this force increasing in power the more horizontal the position of the levers becomes.

As may be seen in the accompanying illustration the levers are double-armed, and on the other end are connected with chains, which can be wound upon pulleys. The less the pressure shall be, which is to be exerted upon the upper roller, that is to say, the thicker the rubber compound is to be spread upon the tissue, the tighter the chains are drawn, and the more the arm of the lever, provided with weights, is raised.

The tissues to be converted into water-proof fabrics are wrapped around a roller, and are wound upon a cylinder after they have been provided with the solution, and sufficiently dried, so that the separate folds will not stick together.

As has previously been mentioned, the more closely woven the fabric is, the thinner the rubber compound can be spread upon it, and there is no

danger of soaking through, which must by all means be avoided. For tissues with a looser texture, a rubber compound of greater consistency has to be employed, as thin solutions would soak through.

The thinner the rubber compound is, the more beautiful and uniform the coating will be, and for this reason it is necessary to apply several coatings to the tissue to render it entirely water-proof. For the first coat the compound should be of sufficient consistency to prevent all danger of soaking through. In many factories the solution or compound is still applied by means of ladles, which a workman fills from a vessel containing the material.

As the tissue advances between the rolls, he pours the solution upon it, and it will be readily understood that considerable skill is required to pour the solution in such a manner as to spread exactly the right quantity. And, as besides the solutions always contain fluids, the vapors of which exert an injurious effect upon the health of the workmen, the manufacture of water-proof tissues in this primitive manner deserves to be called very unhealthy work.

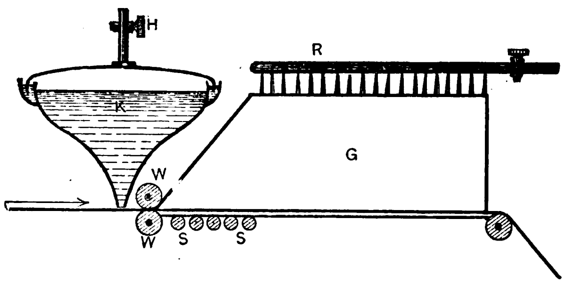
To protect the workmen from the evil effects of the vapors, the tissue, after it has been coated, is brought into a room from which the vapors are constantly pumped.

But this gives only temporary protection, as the workman who ladles the fluid from the vessel and spreads it upon the tissue, to be sure, does not suffer

from the vapors which are formed *behind* the rollers, but is exposed to those developed on *the other side* of the apparatus.

A very simple contrivance, represented by Fig. 13, may be used for removing this evil, and at the same time for spreading the mass as uniformly as possible upon the tissue. This apparatus consists of a sheet-iron box *K*, having the shape of a three-sided prism, which serves for the reception of the solution or compound. The box is placed imme-

FIG. 13.



diately behind the rolls *W*. The lid of the box catches into a gutter filled with water, which prevents the escape of vapors into the workroom.

A cock, *H*, is fitted into the lid, which is only opened at the commencement of the operation, and allows air to enter into the interior of the box as soon as the contents commence to run off. On the lower edge of the box is a slide which closes a slit in the box through which the fluid escapes.

Close to the rolls stands a sheet-iron case, *G*, having the form of a house with a steep roof. It is

somewhat wider than the tissue which slides along upon the bottom of it, and passes out through as narrow an opening as possible. On top of the roof is a pipe, *R*, provided all around with fine holes, and connected with a reservoir constantly filled with cold water. On the sides of the box are several pipes for carrying off the fluid dripping down.

The apparatus works as follows:

A stream of the solution as wide as the tissue to be coated flows through the slit in the vessel, which has been opened just as wide as it is necessary, the rolls spreading it upon the tissue in an entirely uniform layer. The part of the bottom of the box nearest to the rolls, into which the tissue passes, is heated by hot water contained in the pipes *S*. Evaporation of the solvent commences at once, and the vapors rise up to the roof. But this is constantly cooled off by the water falling down like rain, and the vapors, on coming in contact with the cold surface, are condensed, or at least the greater part of them, and run down on the inside of the box, and escape from it through the discharge-pipes, the fluid being collected in flasks placed under them.

The best plan is to arrange the work so that the manufacture of water-proof tissues can be carried on in the cold season of the year. The rolls and the vessel containing the solution should then be put in a heated room, while the sheet-iron box, in which the solvent is condensed to a fluid, is placed in the

open air. With such an arrangement the workmen do not suffer from the injurious vapors, the work can be carried on without interruption, and the greater part of the solvent may be regained.

As a certain quantity of the solvent still adheres to fabrics which have recently been finished, and causes them to be sticky, it is advisable not to wrap them up immediately after they come from the apparatus, but to keep them stretched out for several days as smoothly as possible.

If tissues for the manufacture of garments are to be prepared, a certain quantity of lampblack is added to the rubber compound before its mechanical treatment is commenced, and worked with it for the purpose of imparting a uniformly black color to it.

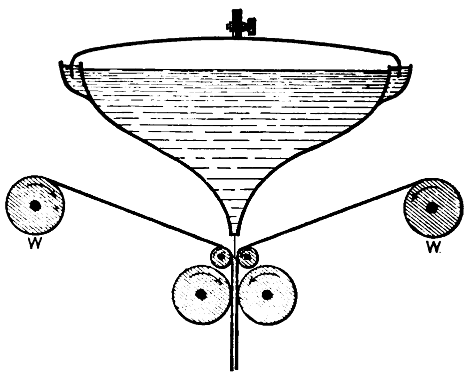
A coating of light brown color is obtained by using rubber in a pure condition. By mixing it with sulphur and heating the ready tissue to the temperature required for vulcanization, the coating will show the peculiar gray coloring of vulcanized rubber.

Tissues with an intermediate layer of rubber. Cut sheets of rubber are no longer used for manufacturing such water-proof fabrics as were first made by Mackintosh, solutions being now generally employed for the purpose. The tissues are cemented together with the assistance of an apparatus shown in Fig. 14.

The tissues having been wound upon the cylinders *W*, are unrolled in the direction indicated

by the arrows and pass through between two rolls placed in a horizontal position. A vessel resembling the one represented in Fig. 13, contains the rubber solution, and is placed exactly over the rollers. The solution is allowed to run from this vessel by opening the slide in the bottom of it as wide as may be necessary, and on reaching the tissues, it is forced into their meshes by the rolls. A second pair of rolls, placed beneath the others

FIG. 14.



and heated by steam, effect the evaporation of the solvent. The finished tissues are hung up for a few days to allow them to become completely dry.

Deodorizing water-proof fabrics. The odor of the solvent adhering for a long time to tissues water-proofed by means of pure rubber, it becomes necessary to remove this odor as much as possible. Exposure to a higher temperature, even for a longer time, is not sufficient for the purpose. More satis-

factory results are obtained by constantly changing the air in the heated chamber in which the tissues are suspended, for instance by conducting a current of hot air through it.

It is a well-known fact that certain bodies which volatilize with great difficulty when left to themselves, do so very readily when brought in contact with hot steam, and this process may be used for removing the disagreeable odor from tissues coated with pure rubber.

The simplest plan is to use the saturated steam as furnished by the steam boiler of the factory. The tissues are suspended in a properly arranged room, and the steam is passed into the latter through several openings. A rather narrow escape pipe for the steam is placed at the other end of the room, and provision must be made for the escape of the condensed water. A pressure of but little more than one atmosphere is sufficient for all purposes, and the tissues will be entirely deodorized after they have been exposed for some time to the action of the steam. Oil of turpentine is frequently employed for dissolving the rubber, especially for goods of an inferior quality. This solvent contains small quantities of empyreumatic substances of a very disagreeable odor, and the latter adheres so tenaciously to the fabrics, as to render its removal difficult by the treatment with steam, and a slight odor always remains behind.

This applies also to coal-tar oils, and for this reason these solvents should be tested before use,

and those possessing a disagreeable odor in a remarkable degree should either be entirely rejected or subjected to a second rectification in order to separate as much as possible the objectionable products.

Manufacture of water-proof fabrics by means of rubber compounds. The use of pure or vulcanized rubber for the manufacture of water-proof fabrics is rather expensive, since, besides the labor required, a large portion of the solvent is lost even with the use of all imaginable precautions.

In order to manufacture water-proof fabrics at a smaller cost, less expensive bodies than rubber are partly used, and in some cases this material is entirely omitted in the composition. Coal-tar and boiled linseed oil have proved good substitutes for a part of the rubber, as they furnish compositions quite suitable for many purposes, for instance, for so-called rubber shoes, they being at present more frequently used for this purpose than pure rubber.

For the preparation of compounds which, besides rubber, are to contain linseed oil, the latter is heated until decomposition takes place. For this purpose it is brought into a boiler of a sufficient capacity to contain at least three times the quantity of oil, as the latter expands very much during heating.

The oil should be heated as quickly as possible to from 302° to 320° F., and kept at that temperature for several hours. The fire is then increased to such an extent that the oil apparently boils, this

being the stage of its decomposition. The heating is continued until a sample taken from the boiler with a wooden spatula runs off in long, viscid threads.

The oil thus prepared possesses the properties of a quickly-drying varnish, and until it is used must be protected against the action of the air to prevent it from drying in. For this purpose, after it has become cold, it is put in a vessel, and is covered with a layer of water.

The purified rubber is dissolved in oil of turpentine, which is generally used as a solvent in this case, and the solution compounded with a certain quantity of boiled oil, the latter depending entirely on the pleasure of the manufacturer, as the solution can be mixed with any desired quantity of it. When the first coating is dry, a second or a third is applied, as may be found necessary, and finally one consisting of boiled oil alone, to which has been added some lampblack or any other coloring matter.

The tissues can be coated by using the same apparatus employed for preparing fabrics with pure rubber, or by stretching them over a frame and applying the composition with a flat brush.

When such tissues have been prepared with proper care, they are especially well adapted for the manufacture of rubber shoes. The separate parts of the shoes are cut from it according to patterns, and cemented together over a last with rubber solutions. The soles are manufactured either of vulcanized rubber or may be made of the same tissue, but

in the latter case either very thick tissues are used or several layers of the fabric, employed for the uppers, are joined together by pressing them while they are still sticky, in order to make the soles more durable.

If it is desired that the boiled oil should dry as quickly as possible, a small quantity of sugar of lead is added to it before it is boiled ; one per cent. of the weight of the oil being sufficient for the purpose.

When coal tar is to be added to the rubber, it must first be boiled, until a mass of the consistency of Burgundy pitch is formed. While still hot, it is kneaded together with and worked in the same manner as pure rubber. This composition can be vulcanized by adding sulphur to it during the mechanical treatment, and subjecting it to the heating process, but the quantity of sulphur added must be somewhat larger than that required for pure rubber.

Water-proof tissues may also be prepared by using a rubber lacquer, which will be described later on. In regard to pliability and lustre, the quality of the coating will largely depend on that of the varnish used.

Rubber felt, felt paper, or *Clark's patent felt*, is used for a variety of purposes, such as covering damp walls, protecting silk and other wares from dampness during water-transit, covering telegraph wire, roofing, etc. Although rubber is now used, gutta-percha, alone or mixed with resins and other mat-

ters, has been employed. A pair of ordinary mixing rolls, running at equal speeds, receive over each a cotton fleece, which is delivered from the carding machines stationed on opposite sides, so that the two fleeces enter together between the rolls, and passing down through an opening in the floor are led away or rolled up. A sort of dough is carefully laid between the rolls, and as the fleeces pass through, the rubber is squeezed into them. The fabric is vulcanized by incorporating sulphur with the rubber mixtures, and heating in the same way as ordinary spread fabrics. If made with a good quality of rubber and naphtha, it should not feel clammy nor soft, but should be dry and tough. Paper can be similarly treated, and for damp walls, etc., would in many cases be as useful as cotton, while much cheaper.

Fabrication of elastic webbings. Genuine elastic webbing can only be manufactured with the use of rubber. Sheets or threads of the latter material may be employed, though sheets are only of secondary importance, threads being chiefly used for the larger portion of these fabrics.

For the manufacture of elastic webbings with the use of sheet rubber, closely woven tissues, the individual threads of which possess a considerable degree of elasticity, have to be employed. The tissues are stretched over a frame brushed over with rubber solution, and then covered with a sheet of rubber which has been stretched in the same manner as that used for threads previously de-

scribed. Upon this sheet is placed the second tissue, also previously brushed over with rubber solution. When dry the fabric thus prepared is exposed to a temperature of from 140° to 158° F. in order to restore the elasticity of the rubber. Sheets of vulcanized rubber, if used, must first be partly desulphurized and roughened with pumice stone to make the solution adhere to them. They are then worked in the same manner as above described.

The threads to be used for webbing must first be subjected to stretching. For this purpose they are placed in warm water and allowed to remain there for some time, whereby they acquire a great degree of ductility. They are then wound upon reels, being strongly stretched during the process, and exposed to as cold a temperature as possible, until they have lost all elasticity. For this reason it is advisable to arrange the work so that the operation of stretching the threads can be done in the cold season of the year.

Threads, which have been properly stretched and cooled off, should not contract when taken from the reels nor show any perceptible elasticity. Should a thread break during stretching, the apparatus is stopped, the place of rupture cut obliquely with a pair of sharp scissors, and the freshly cut surfaces joined by pressing them together.

The weaving of rubber threads is done by forming a kind of net consisting of six or seven threads of any kind of yarn around each thread, and these

overspun threads are then joined together by a woof. They may also be wound upon the beam as a chain and provided with a woof of ordinary yarn.

Another method of preparing elastic webbings, but furnishing a less durable article, consists in placing the threads parallel along-side of each other upon a tissue which has been brushed over with rubber solution, and covering them with a similar tissue. They are then cemented together by passing them through between powerful rolls.

Tissues prepared in either manner are finally finished by passing them through between rolls heated by steam, which impart to them a temperature of from 140° to 158° F. The rubber having become inelastic by exposure to a low temperature, assumes by this its original elasticity. The stretched threads contract and effect also the contraction of the tissue joined with them.

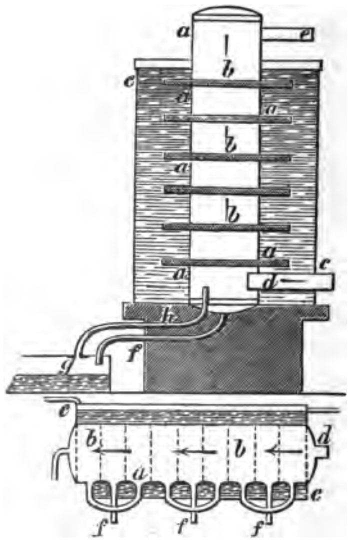
When threads of vulcanized rubber are to be used in the manufacture of elastic webbing, the process must be changed in a corresponding manner, as vulcanized rubber does not possess the property of retaining the length given to it by stretching, but will contract to its original length when the tension is discontinued.

In this case the loom must be so arranged that the threads are firmly stretched while they are woven and the finished woven material must also be subjected to such tension. The power acting upon the tissue is only released when the latter is

entirely finished, when it will contract to the original length of the threads.

Recovery of solvents. For the recovery of vapors of benzene, naphtha and other very volatile fluids used in the manufacture of rubber articles, C. A. Burghardt's condensing apparatus, shown in Fig.

FIG. 15.



15, is very suitable. It consists of a boiler composed of annular pieces *a*, and surrounded by the vessel *c*, which contains the cooling water. Between the annular pieces *a* are fixed steam-tight the cross bottoms *b* of wire-netting in such a manner that outside the boiler they project into the cooling water whereby they are cooled off. The vapors to

be liquefied are conveyed to the apparatus through the pipe *d*, or sucked in by means of a suction apparatus through *e*. In their passage the vapors are condensed on the cooled cross-bottoms *b*, and pass through *f* into the collecting vessel *g*, which is also connected by the pipe *h* with the boiler, the object of this connection being the condensation of any vapors evolving from *g*.

CHAPTER VII.

RUBBER VARNISHES AND LACQUERS.

THE properties of rubber, especially its elasticity and chemical indifference, make it particularly suitable for the manufacture of varnishes and lacquers, and there being a constantly increasing demand for these products, waste which could not be utilized in any other manner can be profitably employed for this purpose.

The first step required is to transform the rubber into a solution, the solvents which have frequently been referred to being well adapted for the purpose. However, in preparing such solutions, many things have to be observed in order to obtain them of uniform quality, and as they are used for many other purposes besides the preparation of varnishes, it will be of interest briefly to describe the method of preparing them.

Preparation of rubber solutions. Rubber solutions for manufacturing purposes are, as a rule, prepared on a large scale, iron vessels hermetically closed being used for the purpose. The rubber is cut up in small pieces, and the solvent should be as free from water as possible.

Although the different varieties of rubber possess,

as a rule, the same chemical composition, they show considerable difference in their behavior towards solvents. While, for instance, one variety may readily dissolve in oil of turpentine, another does so with difficulty. It is, therefore, advisable to make a preliminary test with small quantities of rubber and solvent.

The most favorable results are obtained by adding from 5 to 40 per cent. of highly rectified alcohol to the solvent, the good effect produced thereby being very likely due to the property in alcohol of vigorously absorbing water.

If carbon disulphide or benzene is used as a solvent, special precautions to prevent volatilization have to be employed. The top of the vessel for dissolving the rubber should be provided with a broad rim, upon which a ring of vulcanized rubber is laid, and after the lid of the vessel is placed upon this, it should be held down by placing heavy weights upon it. The vessel is also provided with a stirring apparatus, and in its general arrangement very much resembles that used for bleaching rubber (Fig. 10).

The dissolving power of most fluids is increased by heat, and the solution of rubber can be much accelerated by placing the apparatus in a boiler filled with water and heating the latter. With carbon disulphide the temperature should not be above 104° F., with benzene, not above 140° F., and with oil of turpentine or rectified petroleum not over 212° F. But heating should be done only towards the end of the operation.

Generally 24 to 30 hours are required for effecting complete solution, but as the time may be considerably shortened by heating and repeatedly stirring the mass, it is advisable to arrange the stirring apparatus in such a manner that it is connected by a pulley with the engine of the factory and can be constantly kept slowly revolving.

When the fluid which is formed after the solvent has acted upon the rubber for a sufficiently long time is examined in a glass, it will be observed that it is never uniform, but that small lumps of more or less swollen rubber float in it. These can never be completely dissolved even by using very large quantities of the solvent.

Therefore, to obtain uniform solutions, the mass coming from the apparatus must be subjected to mechanical treatment, and this consists in kneading or squeezing it between rolls. If carbon disulphide or another volatile solvent has been employed, this must be done in a hermetically closed vessel to prevent heavy losses of solvent by evaporation.

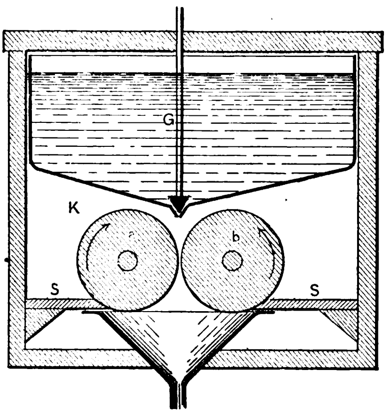
Fig. 16 represents an apparatus which is well adapted for kneading rubber solutions; it is arranged as follows:

Two smooth rolls, *a* and *b*, of equal diameter, lie in a box *K* of wood or iron. The rolls are acted upon by cog-wheels on the outside of the box, in such a manner that they revolve at unequal velocities, and are placed so close together as to leave only a very narrow space between them. The rubber solution to be kneaded is poured into the sheet-

iron vessel *G*, in the bottom of which is a slit running parallel with the rolls. Smoothing blades *S*, pressing closely against the rolls, are placed on both sides of them. The solution which is scraped by the blades from the rolls flows into a collecting vessel, and eventually upon a second, third, or fourth pair of rolls.

To control the flow of solution upon the rolls

FIG. 16.



from the vessel *G*, there is a metallic wedge fitting the slit in the bottom of the vessel *G*. This wedge can be raised and lowered by a rod projecting above the box, and the discharge of the solution regulated thereby. To be able to observe the flow of solution, a pane of glass is fitted into the side of the box.

By repeatedly treating the partly dissolved and partly swollen mass of rubber between the rolls, an entirely homogeneous mass is finally obtained, the

consistency of which will of course depend on the proportions of rubber and solvent. Very thickly-fluid solutions can be used for casting different articles in hollow moulds, somewhat thinner solutions for cementing together pieces of rubber, etc.

By reducing the swollen masses of rubber, which have been made homogeneous by passing them through the rolls, with ether, chloroform, oil of turpentine, etc., fluids are obtained which can be used as varnishes without further preparation. In drying, they leave behind a very thin, nearly colorless film of rubber, and such solutions are well adapted for coating copper plates and maps, which can then be cleansed with a moist sponge.

For many purposes, rubber solutions are not used by themselves, but are mixed with copal varnish, boiled linseed oil, dammar resin, etc. Varnishes prepared with an addition of resin-varnishes, or lacquers, show a strong lustre, while pure rubber varnishes (that is, solutions of pure rubber alone) possess scarcely any lustre whatever.

Below a few receipts for rubber varnishes for different purposes are given :

Leather Lacquer.

Rubber . . .	1 part	by weight.
Dissolved in oil of turpentine . . .	8 parts	"
Mixed with fat copal varnish . . .	6 "	"
Boiled with linseed oil	4 "	"

Varnish for Gilders.

Rubber . . .	1 part by weight.		
Dissolved in rectified petroleum . .	8 parts		"
Mixed with copal varnish . . .	4	"	"

Varnish for Glass.

Rubber . . .	1 part by weight.		
Dissolved in chloroform . . .	60 parts		"
Gum mastic . .	10	"	"

This varnish, which adheres well to glass, may be colored as desired, and with it imitations of flashed glass can be prepared, and glass cemented to glass. It is also well adapted for fastening letters of glass or metal upon glass.

A varnish which, however, dries somewhat slowly, is prepared by cutting up 1 lb. of soft rubber and allowing it to swell up in ½ lb. of ether. The mass is then liquefied by heating in warm water; it is then mixed with 1 lb. of warm pale linseed oil, and after some time with 1 lb. of heated oil of turpentine, and finally filtered.

For varnishing morocco, Champagne recommends the following preparation: Allow ¼ lb. of rubber cut up into small pieces to stand for two days with 1 lb. of oil of turpentine, then stir vigorously and after adding 1 lb. more of oil of turpentine, complete solution by heating in the water-bath. Mix 1½ lbs.

of the solution with 2 lbs. of pale copal varnish and 1½ lbs. of boiled linseed oil, and gently heat for some time until a uniform mixture results.

A flexible varnish is prepared by melting 1 lb. of colophony, gradually adding ½ lb. of rubber cut up in small pieces, stirring until cold, and after adding 1 lb. of hot linseed oil, completing solution by heating.

A water-proof coating for shoes and boots is prepared as follows: Soften 1 part of rubber in hot water, cut it up in small pieces with a pair of scissors, and heat gently together with 1½ parts of lard and 6 parts of fish-oil, until solution is complete. Apply the solution while warm to the leather. It dries in the air to a lustrous coating, and becomes so hard that it does not stick.

A solution for repairing rubber shoes is prepared as follows: Pour 12 to 14 parts of carbon disulphide over 2 parts of rubber cut up in small pieces, and let the vessel containing the mass stand in a water bath at 86° F. until solution is effected. The solution is of a paste-like consistency, and to prevent it from hardening too rapidly, reduce it with a solution of rubber and colophony in oil of turpentine, for the preparation of which melt at a moderate heat 1 part of rubber, add to it ½ part of colophony, and when both are melted together, add sufficient oil of turpentine.

Marine glue. The preparation known by this name is an excellent rubber varnish for protecting wood and metal against the action of water. It

consists of a solution of 1 part of rubber in 12 parts of rectified petroleum, which is combined by heating and stirring with 6 parts of shellac or asphaltum. It should be applied at a temperature of from 266° to 284° F.

Marine glue for damp walls. It is frequently a very difficult matter to keep the basement walls of houses entirely dry. Generally they absorb so much moisture from the ground that the glue which has been mixed with the paint commences to mould, and the painter's work falls off, or in case the room is papered the wall-paper puffs up and becomes stained. These evils can be best avoided by using the following marine glue:

	Parts.
Rubber	10
Whiting	10
Oil of turpentine	20
Carbon disulphide	10
Colophony	5
Asphaltum	5

These substances are put in a large bottle, and this is closed as air-tight as possible. It is then put in a moderately warm place and allowed to stand until the soluble substances have become dissolved; this can be hastened by frequently shaking the bottle. The wall to be dried is first thoroughly cleansed, the glue is then applied with a flat brush, and should be laid on about 8 to 12 inches higher up than the wall appears to be damp. Paper which

will adhere very tightly to it is then laid over the glue while it is still sticky.

The wall-paper can be immediately pasted upon this paper, and if the glue has been prepared with due care, will never fall off, as the wall will always be dry.

Jeffery's marine glue. This consists of rubber 3 parts, undistilled coal tar 36, asphalt 6. The rubber is cut up in small pieces and dissolved in the coal tar, and the asphaltum is then added.

The marine glue obtained in this manner is so hard that it cannot be readily melted over an open fire. When it is to be used, it is first softened in a water-bath, and can then be made more liquid over a coal fire without running the risk of scorching it.

An excellent transparent cement for glass upon glass is obtained by dissolving 75 parts of rubber and 15 parts of mastic in 60 parts of chloroform.

For cementing rubber to metal, a solution of 1 part of shellac in 10 parts of ammonia is used.

Hard rubber lacquer. Waste and broken articles occurring in the manufacture of hard rubber can be used for one purpose only, namely, for the preparation of lacquer.

The pieces of hard rubber are melted in an iron pot and must be constantly stirred to prevent scorching. The melted mass is poured in a thin stream upon iron plates, where it congeals to a brittle mass resembling asphaltum. The latter is broken into pieces, which are put in a bottle, and rectified petroleum, or, what is still better, benzol is

poured over them. The quantity of solvent added must be sufficient to produce a fluid which can be easily applied with a brush. The fluid is allowed to stand for a considerable time, during which the foreign substances mixed with the hard rubber, and which are insoluble in petroleum or benzol, settle to the bottom, and the solution is then poured off very carefully.

Hard rubber lacquer when applied to wood or metal forms a brownish-yellow to black coating which strongly resists atmospheric influences, and for this reason is especially adapted for varnishing machines erected in the open air.

II. GUTTA PERCHA.

CHAPTER VIII.

RAW MATERIAL.

Gutta-percha,* as regards its natural formation and composition is a plant-product similar to rubber. It is obtained from the milky juice of certain trees, and it is also a hydrocarbon composed of about equal parts of carbon and hydrogen.

Historical Review.

Gutta-percha was first brought to Europe, in 1866, by the English traveler John Tradescant, who called it "mazer wood." The sample, which he brought home from his travels, was considered a great curiosity, and may be seen at the present day in the Museum Tradescantium, South Lambeth, London. However, no one took the trouble to examine this new product, and still less to apply it to practical use.

Even at the commencement of the 19th century but little notice was taken of it. Scientists and manufacturers were occupied with the examination

* Latin: *gummi plasticum;* French and German: *gutta-percha.*

of rubber, and gutta-percha was at that time generally considered as a non-elastic, inferior quality of rubber, which could not compete with the Brazilian and East Indian products. Only its defects were seen, and no one had the remotest idea of those qualities which at present make gutta-percha an invaluable material.

In 1832, Dr. William Montgomery, who practiced medicine in Singapore, entered into conversation with a Malay laborer. While talking he observed the handle of a hoe, and he heard with surprise that its substance, however hard it appeared to be, could be softened by immersion into hot water, and could thereupon assume and preserve any desired shape. The experiment being immediately made, the assertion of the Malay was fully confirmed. On further inquiry, that excellent quality of the substance in question was found to have been long known among the natives of Java, where it was used for manufacturing canes and handles of whips, as well as of various other implements, and especially of knives and daggers. Dr. Montgomery procured a sample of this remarkable substance and on experimenting with it, found that this new gum was in certain respects superior to rubber for surgical instruments, since the latter became soon sticky under the influence of the moist warm temperature of the inter-tropical zone. In 1843, he reported his discovery to the Medical Board at Calcutta, and at the same time instructed his friend, Dr. José D'Almeida, to communicate his

discovery to the Royal Society of Arts, which awarded to Dr. Montgomery its gold medal.

For the purpose of experimenting D'Almeida furnished small quantities of the so-called gum to English manufacturers, but these experiments were not encouraging, because the special value of the material was not recognized. However, a portion of the samples reached Paris, and were there utilized for probes and other surgical instruments, which were formerly made from rubber.

In 1845, Lagrénèe, returning from a voyage, procured in Singapore quite a considerable quantity of gutta percha, which he presented to the French Minister of Commerce. The latter placed it at the disposal of some manufacturers, and in the following year, Alexandre, Cabriot and Duclos obtained the first patent for the utilization of gutta percha.

From this patent (July 28, 1846) dates the introduction of gutta percha and the creation of a new industry. It would lead too far to discuss the various stages through which this industry had to pass before gutta percha was thoroughly understood and finally took the place in the industries which properly belongs to it. It may suffice to say that attempts were successively made to use this new product for all articles formerly made of rubber. However, in fact, all these experiments were contrary to the characteristic properties of gutta-percha, the greatest difficulty being that it becomes plastic in the heat. Attempts were made to overcome this

defect by vulcanization, which had been so successful with rubber. But sulphur acts upon gutta percha in an entirely different way from rubber, and thus the hopes which had been entertained were of short duration. However, the discovery of the peculiar properties of gutta percha were made just at the proper time, when dynamic electricity commenced to play an important role. It was found to be an excellent insulating material, and that it remains unaltered in water and especially in salt water, which led to the idea of using it as an enveloping material for submarine telegraph cables. The honor of first constructing telegraph lines insulated with gutta percha belongs to Werner Siemens, who, in 1847, built such a line on a German railroad. Wheatstone, as early as 1837, had the idea of connecting England by telegraph with the Continent, and he considered gutta percha as the most suitable material for use in the construction of submarine cables. However, his idea was first actually carried out by Walter Breit, who, January 10, 1849, laid at Folkstone a submarine cable, two miles long, insulated with gutta percha. In the meantime gutta percha was found to be an excellent material for sharp moulds such as are required in galvanoplasty, and its resistance to acids led to the fabrication of receivers, funnels and tubes for use in chemical factories, photographic and other laboratories.

Occurrence of Gutta Percha.

Most of the gutta percha plants belong to the nat-

ural order *Sapotaceæ* growing in the Malay Peninsula. The most important are:

1. *Dichopsis gutta*, or *Isonandra gutta*, or *Palaquium gutta*. It attains a height of 60 to 80 feet, with a diameter of 2 to 4 feet. The leaves are obovate-oblong and entire, pale-green on the upper side and covered beneath with short reddish-brown shining down. The flowers are arranged in clusters of 3 or 4 in the axis of the leaves. The fruit, about an inch long, is of an ovoid shape, and is eaten by the Malays. The wood is soft, fibrous, spongy, of a pale color, and marked with black lines, these being reservoirs of gutta percha. The gutta as it flows from the tree is of a grayish hue, occasionally with a somewhat roseate tinge.

2. *Dichopsis oblongifolium*. This variety is found in Borneo and differs chiefly from the preceding in having oblong instead of obovate-oblong leaves. The gutta obtained from this tree is excellent as regards uniformity and durability. When free from bark and wood it is very tough and elastic so that it can be folded together without breaking. When dipped in hot water it can be kneaded and moulded without becoming sticky, and on cooling reassumes its former solidity. Its color varies between red and dark brown. Like all other varieties of gutta percha the juice as it exudes from the tree is milk-white, the brown color being imparted to it by being mixed with particles of wood and bark, which in boiling and purifying the gutta yield to it their coloring matter.

3. *Dichopsis calophylla* (Benth. and Hook.) appears to be the *Mayang Baton* mentioned by Seligmann-Lui. It yields a paler gutta of a more reddish color, inferior in quality and stiffness to *Dichopsis oblongifolium.*

4. *Dichopsis selendit* yields a very hard gutta suitable for the manufacture of cables. Mixed with other varieties, it may, however, be also employed for other purposes.

5. *Dichopsis Krantziana*, is a tree called in Cambodia by the natives *Thior*, and in Cochin-China, *Chay*. Botanically it resembles *Isonandra gutta.* The gutta obtained from it is of an inferior quality, and even when mixed with other varieties does not give a product which can be recommended.

6. *Dichopsis pustulatum* was discovered in Perak, and is now cultivated in Ceylon as a gutta percha tree.

7. *Payena Lerii* is the only tree belonging to the variety *Payena* which yields gutta. It was discovered by Brau de St. Pol-Lias. It yields a very fair, red gutta.

8. *Bassia Parkii* is of importance as a gutta percha tree among the Bassieæ.

9. *Mimusops.* The product of this plant is no longer brought into commerce under the name of gutta percha, but as Balata. Under this name it has brought about a special industry which occupies about the same position to gutta percha as the latter does towards rubber, and hence a separate chapter will be devoted to it.

The geographical distribution of the trees producing gutta percha is very restricted, the limits being about 6° N. and S. latitudes and 100° to 120° E. longitude. Many of the best varieties are found only on the hill slopes at a distance from the sea-coast, each variety forming a separate grove of from 200 to 500 trees, with high forest trees above them. They grow best in a rich light loam with a rocky subsoil.

Manner of Obtaining Crude Gutta Percha.

The collection of gutta-percha generally takes place directly after the rainy season, as in the dry season the gutta does not flow so readily, while during the rains, ague and jungle fever are most prevalent, and the gutta is liable to be washed away from the felled trees.

The methods of extracting the gutta-percha are much the same amongst the Malays, Chinese and Dyaks. The trees are cut down just above the buttresses, and for this purpose a staging about 14 to 16 feet high is erected. The tools used in felling are either "billiongs" or "parangs." A billiong is a kind of axe, with a blade of a chisel-like form, and the tang is secured at right angles to a handle by means of a lashing of rattan or cane. The Chinese sometimes use an axe perfectly wedge-shaped. The parang looks more like a sword bayonet, and in the hands of a Malay is a box of tools in itself, as with it he can cut up his food, fell a tree, build a house, or defend himself.

When the tree is felled the branches are quickly lopped off to prevent the ascent of the gutta to the leaves. Narrow strips of bark, about an inch broad and 6 inches apart, are then removed, but not all round the tree, as its underpart in its fall becomes buried in the soft earth, much sap being thus lost. Some natives beat the bark with mallets to accelerate the flow of milk or gutta. The milk flows slowly and rapidly concretes, and, according to its source, may vary from yellowish white to reddish and even brownish in hue. The gutta as it flows is received in hollow bamboos, doubled up leaves, spathes of palms, pieces of bark, cocoanut shells, or in holes scraped in the ground.

According to observations made by Leon Brasse and Seligmann-Lui in the regions of production, gutta-percha is prepared in various ways. Thinner milky juices, like that of *Payena*, are brought in a liquid state into the hut of the native, while thicker juices, such as those of *Dichopsis*, become mixed in exuding with particles of wood and concrete still more during transport. The native removes with the hand the coarsest splinters of wood and bark and then throws the mass into a pot of boiling water. The gutta becomes soft so that it can be kneaded and is converted into a compact mass. Good qualities do not stick to the fingers. The mass is worked into strips as thin and even as possible, whereby the greater portion of the particles of wood come to the surface and can be removed by cold, rubbing or in some other manner. As a rule

this operation is twice repeated. The gutta is then again softened, kneaded, rolled out in sheets, washed and rubbed and folded into blocks of various sizes and shapes. Gutta percha twice cleansed is, of course, much better than the product which has been but once manipulated; yet it is not quite pure, as it still contains a considerable quantity of particles of wood, which, when the gutta-percha is to be used for industrial purposes, have to be removed. In Sumatra the gutta is not purified, but just the reverse, is, as a rule, intentionally adulterated by the addition of quantities of pulverized bark. In the course of all these processes the gutta-percha changes its color. While originally white on exuding from the tree, by being boiled it acquires, in consequence of the admixture of bark and wood, a darker hue, which varies in the different varieties. While the gutta of *Payena* becomes yellowish by the influence of the air, that of *Dichopsis* is only colored by the coloring matter it absorbs during boiling.

Unmixed gutta-percha, *i. e.*, derived from one and the same variety of plant, is seldom found in commerce. When the collector has found a certain quantity of gutta percha of good quality, but not enough to sell it to advantage, he looks around for a tree from which he can get what is lacking. However, not to lose time in hunting, he attacks the first tree he finds and takes all that is offered until the desired quantity is obtained. On returning to his hut he mixes everything together. This custom is so general that it is impossible to procure from the

native dealers samples of each kind. The most successful mixture is frequently designated as *Balam-tembago,* even when the juice of *Dichopsis oblongifolium* is contained in it. Experience, however, has taught the Malays which kinds go well together and which interfere with each other, and in their own interest they take care not to mix the latter.

Regarding the yield of crude product obtained from the different varieties of gutta-percha trees, it would seem that this is largely influenced by geographic and climatic location, the age of the trees, the season of the year when the juice is collected, the mode of felling the trees, manner of gathering the juice, etc. The statements in reference to the yield are at such variance as to leave a doubt of the correctness of any of them. Thus Burke gives the average yield from full-grown trees as 11 ozs. Serrulaz states that a gigantic tree felled in Pahang yielded 13½ ozs., while Wray gives the product of a *Taban merah* tree, 100 years old, as 2 lbs. 5 ozs., and that of a full-grown *Taban putch* tree as 2 lbs 11 ozs. Logan, on the other hand, gives the average yield of a tree, for Johor, as 5½ lbs., and Oxley, for Singapore, as 13½ lbs. No matter which of these statements may be correct, the fact remains that even in the most favorable case the yield of a tree is small, and that with the irrational manner in which the juice is collected, the trees still in existence will become more and more decimated, and that there is danger of a decrease in the exportation and finally of entire exhaustion of the sources.

The question of how to meet this danger has occupied many minds, and finally E. Jungfleisch conceived the idea of overcoming it by a more rational mode of harvesting. An examination of specimens of plants led him to the conclusion that gutta is contained in all parts of the gutta-percha tree, not only in the trunk, but also in other organs, and very likely in far greater quantities than the Malays could extract from them. In his report, in 1892, to the Société d'encouragement, Jungfleisch states that experiments have shown that there are several solvents with the assistance of which gutta-percha can be extracted from the plant-cells, toluene having proved the most effective. It completely dissolves the three constituents of gutta percha—gutta, albane, and fluavile—but with the exception of a small quantity of chlorophyl, very little of the other substances contained in the leaves, bark and wood passes into the solution. The experiments were made:

1. With leaves dried in the air, *i. e.*, leaves exposed to oxidation by the air.

2. With leaves dipped while fresh in antiseptic water and then dried.

3. With dried shoots deprived of their leaves.

4. With dried wood, two years old and deprived of its leaves.

All these parts yielded a considerable quantity of gutta-percha.

The method of extracting the gutta percha by this process is very simple. The pulverized mass,

i. e., leaves, shoots, barks, etc., is heated to about 212° F., and then mixed with a solvent, for instance, toluene, the result being a solution, colored green by chlorophyl. Direct evaporation of the solvent is impossible without injury to the product, and hence the toluene is removed by means of steam of at the utmost 212° F. One part of steam carries off 4 parts of toluene, the gutta-percha remaining behind. For the complete separation of the toluene the steam is allowed to act for some time on the mass kept in motion and at a temperature of 212° F.

Besides Jungfleisch and Serrulaz, D. Rigole, Prof. Ramsay and Dr. E. Obach have occupied themselves with the gaining of gutta percha by extraction, and numerous apparatuses have been constructed for the purpose, which are described in Dr. Obach's "Cantor Lectures on Gutta Percha." London, 1898.

Commercial Gutta Percha.

The principal port of shipment of crude gutta percha is Singapore. Before exportation it generally undergoes examination and classification into parcels according to quality. As received in the "godowns" or warehouses, it presents great diversities in condition, shape, size and color—from crumbling, hardly coherent, whitish or greyish "raw" or "getah muntah" fragments, to reddish or brownish blocks as hard as wood. Sometimes it is made up into all manner of grotesque shapes of animals,

and it is nearly always largely adulterated with sago flour, sawdust, clay, stones, etc. The Chinese are great adepts in assorting and classifying gutta, and frequently prepare from different varieties a certain "standard sample," by cutting or chopping the material into thin slices and boiling with water in large shallow iron pans, keeping the contents constantly stirred with poles, and adding good gutta-percha and even cocoanut oil to give a better appearance. When sufficiently boiled the gutta-percha is pressed into large moulds, and is then ready for shipment. This process of reboiling is wholly unnecessary, and in some cases is done only to get rid of stuff which has no right to be called gutta-percha.

A brief summary of the best known varieties of gutta percha, including their commercial names, place of origin, form in which they are brought into commerce, appearance, properties, etc., is given below :

Pahang. *Origin :* State of Pahang, east coast of the Malay Peninsula. *Form :* Generally small pieces. Pear-shaped pieces weigh 1 to 2 lbs.; rectangular oblate pieces, at the utmost 6 lbs. 6 ozs. *Appearance :* Yellowish ; seldom red ; mostly playing into greenish. *Cut surface :* White-yellowish ; very seldom yellow-reddish ; compact, seldom foliated. *Nature and quantity of impurities :* Some particles of wood ; 30 per cent. *Valuation :* This quality works up very well, remains for a long time very nervy, and on cooling rapidly regains its

original hardness. *Nature of the thread:* Somewhat wrinkly.

Sandakan. Origin: In the North Eastern part of Borneo. *Form:* Loaves in the shape of a parallelopiped with trapeziform base and boat-shaped elongation, weighing 4 lbs. *Appearance:* Pale yellow. *Cut surface:* White-yellowish, very seldom yellow-reddish; compact, seldom foliated. *Nature and quantity of impurities:* Small quantity of bark; 22 per cent. *Valuation:* Like the preceding. *Nature of the thread:* Smoother than the preceding.

Maragula. Origin: Not known. *Form:* Very flat loaves weighing 2 lbs. or less. Also flat or four-cornered pressed spindles weighing 6 to 8 lbs. *Appearance:* White-gray, with grayer spots. *Cut surface:* Horny. *Nature and quantity of impurities:* The mass contains no irregular particles of bark, but regular cut pieces are found which no doubt have been intentionally added; 16 per cent. *Valuation:* Very hard, rapidly cooling gutta. *Nature of the thread:* Wrinkly.

Bagan. Origin: Very likely between Malacca and Singapore. *Form:* Pear-shaped pieces weighing 4 to 6 lbs.; or turnip-shaped pieces weighing 12 to 17 lbs. *Appearance:* Wine-red; feels, either cold or warm, like soap. *Cut surface:* More or less rugged; numerous holes due to the imperfect cementing together of the separate pieces of which the large pieces are composed. *Nature and quantity of impurities:* Either none or few particles of bark; 29 per cent. *Valuation:* Quite hard, nervy, and

rapidly cooling gutta. *Nature of the thread:* Very smooth. Smells of opium; is difficult to cleanse; resembles very much balata in its behavior in cleansing and spinning.

Banjer-massin. Origin: South Borneo. *Form:* Clubs about 32 inches long and 3¾ to 5¾ inches in diameter, rounded off on both ends. Also parallelopipeds ornamented on both sides with sculptures, a monster upon one side and foliage upon the other. *Appearance:* Spongy, brown, even blackish. *Cut surface:* Salmon-red, foliated. *Nature and quantity of impurities:* Many particles of bark; 45 per cent. *Valuation:* Very hard, very nervy, rapidly cooling gutta. *Nature of the thread:* Wrinkly.

Kotaringin. Origin: South Borneo. *Form:* Spindles pointed on both ends, the cross-section of which is square or oblate, and which weigh 2 to 4 lbs. Also parallelopipeds rounded off and reduced on the ends and weighing 6 to 8 lbs. *Appearance:* Paler than the preceding. *Cut surface:* Salmon-red, foliated. *Quantity of impurities:* 32 per cent. *Valuation:* Somewhat less nervy than Banjer-massin. *Nature of the thread:* Wrinkly.

Pekang. Origin: In Pekang on the sea-coast. *Form:* Loaves 1½ to 1¾ inches thick and weighing 4 to 11 lbs. *Appearance:* Brown-reddish, dark plume-color, mouldy. *Cut surface:* Wine-red, very homogeneous. *Nature and quantity of impurities:* 23 per cent. *Valuation:* Not very hard or nervy; cools with difficulty. *Nature of the thread:* Smooth.

Sarawak. Origin: Northwestern part of Borneo.

Form: The loaves, when dry, are light in proportion to their size. *Appearance:* Spongy loaves; the surface is warty with earth-brown bark. *Cut surface:* Yellow-reddish with white veins. *Nature and quantity of impurities:* Many particles of bark; 50 per cent. *Valuation:* Very good quality; very nervy; cools rapidly. *Nature of the thread:* Wrinkly.

Pontianak. *Origin:* Southwestern portion of Borneo. *Form:* Blocks weighing 11 to 22 lbs. *Appearance:* Very spongy, yellow-reddish, grayer than Sarawak. *Cut surface:* Like Sarawak, gray or with white veins. *Nature and quantity of impurities:* Many impurities; 44 per cent. *Valuation:* Very good gutta. *Nature of the thread:* Wrinkly.

Pedang. Origin: West Sumatra. *Form:* Flat parallelopipeds weighing about 4 lbs. each. Each of them bears the stamp of its origin. Also larger loaves weighing up to 66 lbs. *Appearance:* Very pronounced yellow-reddish. *Cut surface:* Like the outside; perceptibly foliated. *Nature and quantity of impurities:* Many impurities; 40 per cent. *Valuation:* Hard and nervy; cools rapidly. *Nature of the thread:* Nervy. This gutta-percha cannot be used nnmixed for electrical purposes.

Sarapong or Souni. *Origin:* East Sumatra. *Form:* Oval loaves running to a point on both ends, and weighing from 1 to 2 lbs. *Appearance:* Surface wrinkly, earthy. *Cut surface:* Homogeneous, white-yellowish. *Nature and quantity of impurities:* Very pure; 30 per cent. *Valuation:* Inferior

quality ; quite hard but not very nervy ; cools well. *Nature of the thread:* Very smooth.

The term Souni is applied to a series of mixtures prepared by the natives of Sumatra, which contain white and red gutta in varying quantities. Seligmann-Lui saw the following mixture prepared: Gutta Derriam (*Dichopsis oblongifolium*) 2 parts, Sundeck (*Payena Lerii*) 3 parts, Pontch (Boula-Balam) 1 part. Sarapong is a type of a good mixture suitable for telegraph wires.

Siak. Origin: East Sumatra. *Form:* Clubs thicker in the centre and weighing from 4 to 7 lbs. *Appearance:* Yellow-reddish. *Cut surface:* Paler, foliated. *Nature and quantity of impurities:* Very much bark ; 50 per cent. *Valuation:* Quite hard but not very nervy; cools quite well. *Nature of the thread:* Very smooth.

Bolungan. Origin: East Borneo. *Form:* Clubs provided on top with a loop which is formed by folding the thinner portion of the club upon the thicker, and several times twisting this end. The best quality comes in small loaves weighing 4 to 10 lbs., also larger loaves weighing up to 66 lbs. *Appearance:* Blackish, almost sooty; knotty. *Cut surface:* White or violet color; foliated. A juice exudes which, on exposure to the air, immediately hardens upon the knife. *Nature and quantity of impurities:* Very pure, but adulterated with pieces of bark all of the same shape and very likely obtained from the tree producing the gutta. *Valuation:* Hard, nervy ; cools well. *Nature of the thread:* Wrinkly.

Coti. Origin: East Borneo. *Form:* Pieces of even size. Rolls 32 inches long and 5¾ inches in diameter. They are formed of thin leaves rolled up; the ends have been turned back with the hand and show the imprint of the fingers which have kneaded the gutta. *Appearance:* Like covered with a net. The meshes of the net are filled with yellow or yellow-reddish particles of wood. Many pieces bear a stamp and are then mostly somewhat reddish. *Cut surface:* Perceptibly foliated, white-yellowish or grayish, and like Bolungan separates a viscous liquid. The cut surface of the stamped pieces is more reddish. *Nature and quantity of impurities:* But little bark; 30 per cent. The stamped pieces contain more bark. *Valuation:* Hard, quite nervy, cools well. The stamped pieces are of better quality. *Nature of the thread:* Quite smooth.

Cotonan. Origin: Unknown. *Form:* Small, flat loaves weighing 4 to 6½ lbs. *Appearance:* Surface very smooth. *Cut surface:* Very white; separates a viscous fluid. *Nature and quantity of impurities:* Little or no bark, but much water; 30 per cent. *Valuation:* Hard, but not nervy; cools well. *Nature of the thread:* Very smooth. The separated fluid smells like rotten cheese. Loss in washing, 30 per cent., of which only 2 per cent. is solid constituents.

Kelatan. Origin: Northeastern part of the peninsula Malacca in the northern portion of Pahang. *Form:* Balls of thread analogous to the African rubber balls and weighing 1 to 2 lbs. *Appearance:* In a fresh state rose-color and wax-like; when older,

chalk-white. *Cut surface:* Very white, separates a viscous fluid. *Quantity of impurities:* 30 per cent. *Valuation:* Very friable; on the whole not very hard; does not cool well. *Nature of the thread:* Very smooth.

Under this name two kinds of gutta percha are known. On examining the one kind, it is plainly seen that it is just as it has been collected. This is known as gutta vierge. The second kind consists of two parts, a core of inferior quality coated with a layer of better quality. This variety becomes brittle in a short time.

Pahang-white. *Origin:* Pahang. *Form:* Balls of a size larger than a head. *Appearance:* Chalk-white. *Cut surface:* Friable. *Quantity of impurities:* 40 per cent. *Valuation:* Quite nervy, viscous; cools well. *Nature of the thread:* Very smooth, but difficult to work by itself, as it sticks to the cylinder. The surface of this variety frequently consists of a layer of nervy gutta only a few millimeters thick. Smells of fresh cheese.

Assahan. *Origin:* Northeastern part of Sumatra. *Form, Appearance* and *Cut surface:* Same as Pahang-white. *Quantity of impurities:* 20 per cent. *Valuation:* Somewhat inferior in quality to Pahang-white, it being more viscous and does not cool as well. *Nature of the thread:* Same as Pahang-white.

Tringanon. *Origin:* Northeastern part of the Malay Peninsula on the shores of the Kelatan. *Form, Appearance, Cut surface:* Same as the preceding. *Quantity of impurities:* 31 per cent. *Valu-*

ation and *Nature of the thread:* Same as the preceding.

Boula-Balam. Origin: Malacea. *Form:* Shapeless pieces which must be quickly pressed into blocks as otherwise they crumble to dust. *Appearance:* Chalk-white. *Cut surface:* Friable. *Quantity of impurities:* 31 per cent. *Valuation:* A soft gutta without nerve. The pieces stick together even after cooling for several days. To prevent them from forming a mass they must be dusted with talc powder.

The tree producing this gutta grows in the marshy regions of the gutta-percha countries. Nearly all varieties of gutta are adulterated with this quality. Notwithstanding its low price, but little of it is used, which is very likely due to the fact that enough of it is contained in the white gutta by the addition of which the working of the good brands is only rendered possible.

Statistics. As previously mentioned, Singapore is the principal and almost exclusive market for the export of crude gutta percha. From statements taken from the Straits Settlement Government Gazette and the Blue Books, and from the statistical reports of the British Custom House, Dr. E. Obach calculates the quantity of crude gutta percha brought to Singapore for the years 1885 to 1896, as 542,081 cwts., valued at £3,547,787, which gives an average price of 14 pence per pound. According to the same sources, the export of crude gutta percha from Singapore from 1885 to 1896, inclusive, amounted

to 619,377 cwts., valued at £4,855,794, which shows that the export during that time was 77,296 cwts., valued at £1,308,007 greater than the receipts. Hence this excess must have been taken from stock on hand prior to 1885. According to the quantities shipped direct from Singapore, the countries into which the product was imported may be arranged as follows:

England	470,770 cwts.,
France	54,215 cwts.,
Germany	47,151 cwts.,
United States	37,894 cwts.,
Asia	4,241 cwts.,
Holland	4,202 cwts.,
Italy	895 cwts.,
Total	619,377 cwts.

This shows that of the total amount exported from Singapore more than two-thirds went to England.

The re-export from England amounted in

1885 to	9,666 cwts.,	1891 to	6,408 cwts.,
1886 to	11,528 cwts.,	1892 to	7,989 cwts.,
1887 to	8,824 cwts.,	1893 to	7,430 cwts.,
1888 to	8,373 cwts.,	1894 to	9,975 cwts.,
1889 to	8,304 cwts.,	1895 to	12,536 cwts.,
1890 to	11,456 cwts.,	1896 to	14,497 cwts.

Hence, not quite theee-fourths of the total importation remained in the country for home consumption, and in stock.

From the English re-export

Germany received about.	48,100 cwts.,
France received about .	26,000 cwts.,
Holland received about .	16.400 cwts.,
United States received about	11,500 cwts.,
Other industrial countries received about . .	11,300 cwts.,
English colonies . .	3,700 cwts.

The principal markets for gutta percha in Europe are Liverpool, London, Marseilles, Rotterdam and Hamburg.

CHAPTER IX.

CHEMICAL AND PHYSICAL PROPERTIES OF GUTTA PERCHA.

In view of the diversity of its origin and the rare occurrence of a pure, unmixed commercial article, *i. e.*, such as is derived from one and the same plant, it is impossible to determine the physical, and still less so the chemical, properties of gutta percha as absolutely pertinent to all cases. The following statements are based upon observations and experiments made in the best markets, and, generally speaking, may be considered correct.

Pure gutta percha is colorless and in thin sections transparent. If a thin slice, about $\frac{1}{5}$ millimeter thick, is laid upon a white support, it shows, however, a specific coloration between rose color and gray-white. It is tasteless and odorless, and a characteristic pungent odor occasionally evolved by it, is due to decomposition. It is of a cellular structure, but when vigorously stretched it becomes fibrous. In this condition it is very strong in the direction of the pull, but its strength decreases in the crosswise direction, and it breaks readily when pulled that way. At the ordinary temperature separate pieces do not unite, but when their surfaces are slightly heated and pressed together, they com-

bine to one piece, the original separate parts of which cannot be restored.

At the ordinary temperature gutta percha is compact, pliant, very tough, but shows little elasticity. It can without injury be folded, knotted and extended, and is readily comminuted with pointed or cutting tools. In elasticity it resembles soft leather. Its specific gravity is generally given as from 0.999 to 0.976, but it is actually specifically heavier than water. Thin lamillae of it laid upon water and placed under the receiver of an air pump, sink as soon as the air is exhausted, the numerous small pores having absorbed water. Payen, on stretching gutta percha under strong pressure and immediately cutting the strips thus produced into very small pieces under water, found that the greater part of the fragments fell to the bottom of the vessel, some immediately, others after absorbing a certain quantity of water.

The pliability of gutta percha increases rapidly at between 76° and 86° F., and at 122° F. it yields readily to slight pressure. At 194° F. it becomes plastic so that it can be kneaded, and brought into any desired shape, which it retains unaltered when brought back to the ordinary temperature. If carefully heated to 248° F. it melts, and if still further heated it boils up and yields a colorless oil. It is inflammable at a certain temperature, and burns with a bright flame and leaves behind a black residue.

Towards cold, gutta percha is less sensitive than

rubber, it suffering no alteration at 14° F. Cold water has no effect upon it, except, as previously mentioned, that its exterior pores absorb a small quantity of it.

Examined in thin sections under the microscope it seems to possess a porous structure. Rubber under these conditions shows little or no change of color, while gutta percha exhibits a beautiful spectacle. It appears to be built up of prisms of every variety of hue. Prof. Page states that it resembles more nearly some specimens of ice which he has examined, than anything else. The porous structure may be observed by allowing a drop of solution in carbon disulphide to evaporate spontaneously on a glass slide. The solution is soon reduced to a whitish film and the numerous cavities with which it is pierced may be distinctly perceived. These cavities may be made more visible by means of a drop of water; the liquid gradually insinuates itself, the mass appears more opaque and the cavities are seen to be enlarged.

Gutta percha is a bad conductor of heat and a worse conductor of electricity. When vigorously rubbed it becomes itself electric, and when rubbed with silk throws out electric sparks. As regards resistance to the electric current, no other plastic material is even approximately equal to it, and it retains this property unaltered in the ground or in water.

Towards most solvents gutta percha is entirely indifferent. In cold water it is entirely insoluble,

and while it becomes soft in boiling water or in steam, it is thereby not changed in any respect. In cold weak alcohol it is almost insoluble, but in stronger alcohol its solubility increases and the more so the higher the temperature becomes, it losing, in boiling absolute alcohol, 15 to 20 per cent. of its constituents. It is partly soluble in oil of turpentine, olive oil and a few mineral oils, and more soluble in bezene. The best solvents for it are carbon disulphide and chloroform.

According to analysis gutta percha consists of a combination of hydrocarbons, the composition of which resembles very much those of rubber. The oxygen which is found in it very likely belongs to a foreign combination. Gutta percha contains:—

Carbon	86.36
Hydrogen	12.15
Oxygen	1.49
	100.00

As far as the chemical composition of gutta percha is concerned, it must not be considered as a single combination, but as a mixture of several bodies which occur in different quantities in different varieties of it. Two of these combinations can be dissolved by boiling in anhydrous alcohol, and if the solution is allowed to stand quietly for some time, small white grains are separated, the surface of which consists of numerous small crystals, but contain a yellow, amorphous core in the centre.

The yellow non-crystalline mass can be more

easily dissolved in cold alcohol than the crystals, and according to this, gutta percha, by a suitable treatment, can be separated into three parts, one of which (gutta) is insoluble in alcohol, the next (albane) is difficult to dissolve, while the third (fluavile) is easily dissolved.

Payen, who thoroughly examined gutta percha, found in 100 parts of it:

	Per cent.
Gutta	78 to 82
Albane	16 to 14
Fluavile	6 to 4

Pure *gutta*, which remains after the crude gutta percha has been thoroughly exhausted with alcohol, is a white mass, which, when rolled into thin sheets, is tenacious and ductile at a temperature of from 59° to 86° F., but not very elastic. It becomes soft when heated to 113° F. and assumes a yellowish color; the higher the temperature the darker and more transparent becomes the mass, and finally becomes dough-like but without actually melting. It melts when the temperature is raised to 248° F., and commences to decompose at a still higher temperature. Towards solvents its behavior is the same as that of gutta percha.

Albane is the crystalline resin which is separated from the solution in boiling alcohol. It melts at from 347° to 356° F. If exposed to a still greater heat it is decomposed and furnishes the same products as gutta.

Fluavile is a non-crystalline resin of an orange

color. It is hard at an ordinary temperature, but becomes soft when taken in the hand, melts between 212° and 230° F., and is decomposed when heated still more, emitting at the same time pungent vapors.

Recent investigations have clearly established the relation between gutta, albane and fluavile. According to these investigations it may be supposed that the body which is of actual industrial value, namely, the pure gutta, is a hydrocarbon, being composed, according to *Baumhauer*, of $C_{20}H_{32}$. If we compare the formula for the composition of pure rubber (C_5H_8), established by Williams, with that of gutta, it will be seen that the formula of the latter is equal to four times that of the first, and that, therefore, the two bodies show great similarity in regard to their chemical constitution.

Besides gutta ($C_{20}H_{32}$), according to *Baumhauer's* investigation, two more combinations are found in the crude gutta percha. These are composed of $C_{20}H_{32}O$ and $C_{20}H_{32}O_2$, and are, therefore, products of oxidation of gutta. We might suppose that these products were already present in the fresh milky juice itself, but from the fact that, if gutta percha is stored for any length of time, its properties undergo an essential change, we must conclude that new products of oxidation are constantly formed.

Mr. Clark carried out a series of experiments upon gutta percha, and below the results as interpreted by W. A. Miller are given :

500 grains of a thin sheet of gutta percha were exposed for eight months under the following conditions:

1. In netting open to the air and light, but excluded from rain.

2. In a bottle open to the air and light, but excluded from rain.

3. In a bottle open to the air, but excluded from light.

4. In fresh water, open to air and light.

5. In fresh water, open to air, but excluded from light.

6. In fresh water, excluded from air and light.

7. In sea water, exposed to air and light.

8. In sea water, excluded from light, but exposed to air.

9. In sea water, excluded from light and air.

The specimens 4, 5, 6, 7, 8 and 9 were wholly unaltered, with the exception of a slight increase in weight, due to the absorption of water, which they lost again after exposure to the air for one or two hours. The tenacity and structure of the material did not appear to have undergone the slightest change.

No. 2, which had been folded up and introduced into a bottle, the mouth of which was open and inverted, had absorbed 5 per cent. of oxygen, 55 per cent. of the mass being converted into resin. The outer layers, exposed to light, were brittle and resinous, but the inner portions, screened from light by the outer folds, were but little altered in texture or appearance.

No. 3 had experienced little or no change, had increased in weight only 0.5 per cent., and yielded to alcohol only 7.4 per cent. of resinous matter.

Another sample which had been exposed to the light of day for a period of only two months, had become quite brittle, had increased in weight 3.6 per cent., and yielded 21.5 per cent. of resinous matter to alcohol, while a piece of the same sheet, kept in the dark, had undergone no sensible change.

Miller also examined several specimens of cables which had been submerged for periods of time varying from a few weeks to seven years. *In no case where the cable had been completely and continuously submerged, did he find any sensible deterioration in the quality of the gutta percha.* The only perceptible chemical difference in the various specimens was in the quantity of water mechanically retained in each.

One of the principal properties of gutta percha is its great chemical indifference. Concentrated alkaline solutions as well as not too concentrated acids, and all saline solutions, do not affect it in the least. It only commences to char when subjected for a long time to the influence of concentrated sulphuric acid; but fuming sulphuric acid brings about a quicker change, and transforms it into a slimy substance.

Even the strongest hydrochloric acid seems to have but little effect upon it; the only effect observed, after lying for months in the acid, being that it had lost some of its pliability. But cold

concentrated nitric acid acts very energetically upon it, and, when boiled, dissolves it completely under the emission of red vapors.

Its chemical indifference and great plasticity make this body absolutely invaluable for certain branches of chemical industry. As it is entirely indifferent towards hydrochloric acid, it is used for manufacturing hose for drawing the acid from the vessels containing it, and is even employed for lining boxes in which the acid is to be transported.

It is also indifferent towards not too concentrated hydrofluoric acid, and is, therefore, employed for manufacturing vats which are to be used in etching glass, and, also, bottles in which the acid is to be kept.

CHAPTER X.

TREATMENT OF CRUDE GUTTA PERCHA.

PREVIOUS to actual use for manufactnring, crude gutta percha, as brought into commerce, must be subjected to a series of preparatory manipulations, the chief object of which is the removal of foreign constituents, such as sand, earth, wood, bark and other impurities. Various methods are employed for this preparatory work, all of which are quite simple.

Before commencing the treatment of the crude material, it is best to more closely examine its condition. This is done by taking at random a few pieces from the mass to be tested and cutting them up with a knife. If it is found that the impurities consist only of pieces of wood, bark and earth, the gutta percha can be at once brought into the cutting machine. But if it is found to contain stones, it should be subjected to a special operation before it is cut up, since if this precaution is neglected, not only the cutting machine might be ruined, but accidents might also happen.

For the purpose of removing stones, the gutta percha is softened in water of about 122° F., and is then rolled out into thin bands. To prevent the rolls from being stopped or injured by the stones,

they are so arranged that the upper one runs in movable brasses held in place by a lever. In case a stone gets between the rolls, the upper one lifts up and falls down again as soon as the stone has passed through.

By forming the gutta percha into bands in the above-described manner every stone can be immediately detected and removed. The bands, while still warm, are folded together so as to form loose blocks of a size corresponding to the cutting machine.

The same kind of machine used for cutting up rubber may also be employed for gutta percha, but, as a general rule, machines of special construction are provided for the purpose. Among these the drum slicing machine and the wheel slicing machine deserve special notice.

The drum slicing machine consists of two circular disks made to revolve as quickly as possible by a pulley, and are connected with each other by a large number of obliquely-set knives placed upon the surface of the cylinder. A vertical cylindrical pipe is placed underneath the cutting machine, and in this is fitted a piston which is pressed upwards by a lever suitably weighted.

A cube of gutta percha is placed in the vertical pipe and pushed by the piston against the knives of the revolving disk, and cut into thin slices.

The wheel cutting machine resembles a straw cutter. It has a fly-wheel about 6½ feet in diameter, with the knives fastened to its spokes. The wheel makes from 500 to 600 revolutions per

minute. The block of gutta percha is placed upon an inclined plane and is fed to the knives which cut it up in very thin shavings.

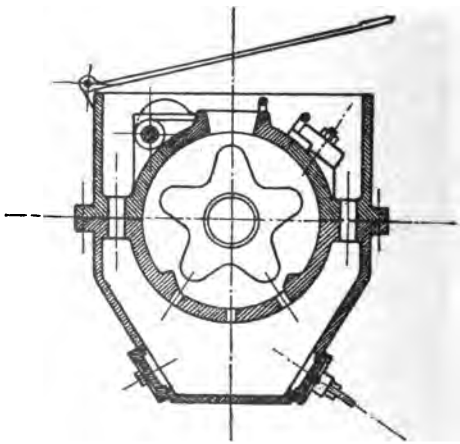
The shavings thus obtained are placed in cold water to separate the heavy admixtures from the gutta percha which floats on the surface. The gutta percha is then brought into vats filled with hot water, in which it remains until it is soft and the shavings combine to a plastic mass.

In this condition the gutta percha is suitable for the manufacture of many articles for technical and other use; but for special, particularly electrical, purposes, a further very careful treatment for the removal of all traces of water and air bubbles becomes necessary. Gutta percha intended for insulating electric cables must form a thoroughly uniform, homogeneous mass, and to attain this object it has to be subjected to a series of other manipulations.

For this purpose, it is first brought into the actual washing machine. This consists of an iron box which can be closed by a lid. In the interior of this box is a hollow iron cylinder which contains an iron roll with a star-shaped cross section, Fig. 17. The cylinder is provided with a lid through which the gutta percha is introduced. The box and cylinder are filled with water, which is heated by steam directly introduced. If now the roll in the interior of the cylinder is set in motion by a transmission on the outside of its axis, the gutta percha is forced, in constantly changing form,

through between the walls of the cylinder and the deep indentations of the roll. To still further increase the effect, two nose-like rails are fixed on the bottom of the cylinder which contract the space between the cylinder and roll. The impurities washed from the gutta percha by this process fall to

FIG. 17.



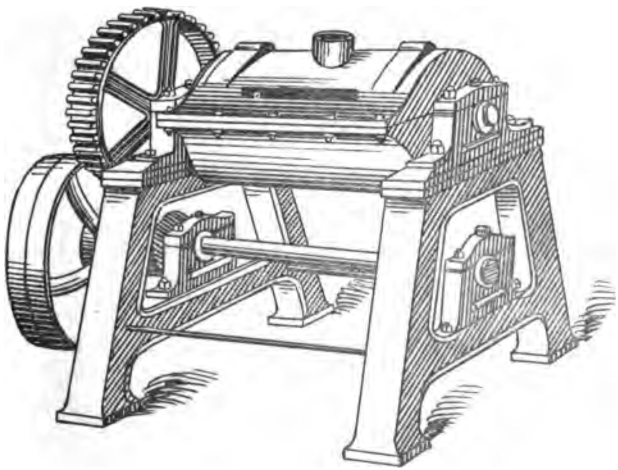
the bottom of the cylinder and through small apertures reach the bottom of the box, from which they are from time to time removed through small doors.

The gutta percha is next brought into the kneading machine, Fig. 18, which closely resembles the washing machine, except that the exterior box is wanting.

In the interior of the machine is a corrugated

roll, the corrugations running either parallel with the axis of the roll, or with more or less twist, spirally around it. The operation of kneading is similar to that of washing, the water of course, being omitted. The temperature required is pro-

Fig. 18.



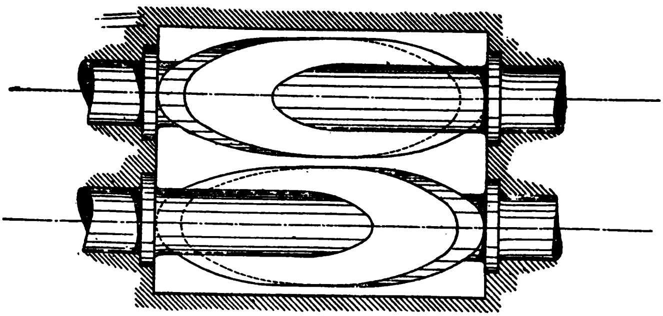
duced by the introduction of steam in the space between the double walls of the cylinder.

There are also kneading machines in which work two horizontal rolls placed one alongside the other, either a corrugated and a smooth roll being used, or two rolls of the same kind, with elliptic disks pushed obliquely over them. The rolls of this latter construction are placed so that the disks cross each other, Fig. 19.

From the kneading machine the gutta percha is

brought into a press or strainer, which consists of a cylinder provided on the lower end with several sieves of different-sized meshes, arranged one above the other, or with several perforated bottoms with different-sized holes. The meshes of the sieves or the perforations of the bottoms diminish in size from above to below, so that the uppermost are the widest and the lower ones the narrowest. The whole is terminated by a bottom with perforations

FIG. 19.



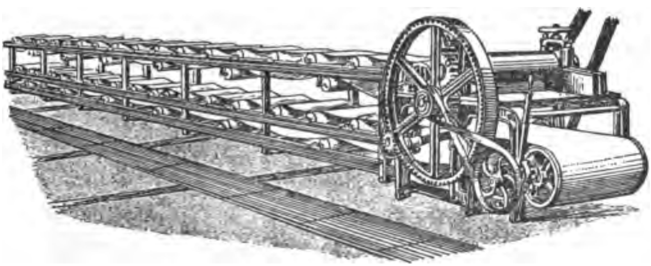
of any desired size. The soft gutta percha is forced through the machine by an accurately-fitting piston. In place of the strainer, ordinary filter presses are also used.

By these various operations the gutta percha is thoroughly worked so that any water and air still contained in it are separated, and a homogeneous texture is formed. In order to be able to store the material more conveniently for future use and at the same time to have it in a more handy form for

working, it is, after coming from the kneading machine or press, rolled into thinner or thicker sheets. The machine used for this purpose, Fig. 20, consists of two rolls with very smooth surfaces placed either vertically or obliquely one above the other, and in general corresponds to the calender employed in working rubber. The mass is introduced from the front of the apparatus, and on leaving it on the back, is taken and carried along by an endless cloth.

As in most cases quite definite demands regarding

FIG. 20.



density, elasticity, electric and other qualities are made on the finished products, and these qualities are seldom or never found in the required degree and proportion in a given kind of raw material, the manufacturer must endeavor to produce them by mixing different varieties. Study and experiments have led to good results in this respect, but, as with rubber, the knowledge thus acquired is kept secret by the various factories.

Gutta percha is seldom mixed with foreign con-

stituents, and in factories particular about quality, it is never done, because by all such admixtures the quality is impaired, which cannot be justified by an eventual cheapening of the price. For incorporating the admixtures, the same machines as for kneading are employed.

Like rubber, gutta percha suffers considerable loss by washing and kneading, the percentage varying very much according to origin, quality and other conditions. The best varieties lose as a rule 15 to 20 per cent. in weight, medium qualities, 20 to 25 per cent., and inferior ones, even as much as 50 per cent.

CHAPTER XI.

INDUSTRIAL APPLICATION OF GUTTA PERCHA.

THE further working of the cleansed gutta percha, *i. e.*, the preparation of the various articles for which it is employed, is similar to the manufacture of articles from non-vulcanized, mixed and rolled rubber sheets. Generally speaking, the manufacture is more simple, because gutta percha is even more plastic and moldable than rubber, and the seams can be readily cemented together.

In many cases, gutta percha replaces leather, and for some purposes it is preferable to it. It is especially useful for articles exposed to moisture, damp cold and acids, and for that reason is employed in the form of hose for conducting cold water, beer, vinegar, wine and acids; for belts running in wet places; for buckets, ladles, shovels, bottles, siphons, funnels and spigots in chemical factories. It is largely used in galvanoplasty for the preparation of moulds and matrices. It is also employed for surgical purposes. When perfectly pure it serves for filling hollow teeth and for the manufacture of plates for artificial sets of teeth, and rolled out to the thickness of paper for different surgical bandages and compresses. In the form of very thin taffeta it is used for sweat bands in hats and caps. An important

application of gutta percha is its use for coating quick-matches so that they can be carried through water without injury to the priming composition. However, the most important use of gutta percha is as insulating material for electrical wires, especially for submarine and underground cables.

Articles are moulded from gutta percha by working it by hand, whilst in a soft and plastic state, into the required form. It needs very careful, though not skilled, labor. To prevent it sticking to the hands or fingers, they should be wetted with water containing a little soap, taking care to remove all traces of moisture when jointing is required. It is kept soft in water heated by steam. Picture frames and similar articles are made in metallic moulds.

Gutta percha hose. Special machines are used for manufacturing gutta percha hose. In their construction they closely resemble presses used for manufacturing drain pipes from clay, and may be described as follows:

A pipe, which determines the outer diameter of the hose to be manufactured, is fitted in the centre of the bottom of a strong iron cylinder. A round core having a diameter equal to the interior diameter of the hose sticks in this pipe.

When the cylinder has been filled with the material, a strongly wrought disk, which acts as a piston, is placed in it and pressed slowly forward, but with great force, by a rack and pinion. To obtain long and perfect hose, great care must be

observed in charging the cylinder with the gutta percha softened by heat, it being absolutely necessary that the entire space be filled without the occurrence of air bubbles.

To attain this object the work is done as follows: The gutta percha is divided into small balls about the size of a fist and heated; as soon as the mass has become sufficiently soft the balls are placed in the cylinder, two men being required for this work. While one workman throws the heated balls into the cylinder, the second stamps them with a flat pestle into a homogenous mass. This labor is continued until the cylinder is filled up so far as to just leave room enough for putting the piston into position.

After completing these operations, steam is admitted into the steam-jacket to heat the contents of the cylinder, which may have cooled off somewhat while putting them into the cylinder, and the heat is maintained until the mass is entirely soft. The actual work is commenced when a small test proves that the gutta percha can be worked without difficulty.

The hose upon leaving the machine has a consistency not much greater than flour dough, and must be cooled off as rapidly as possible to an ordinary temperature in order that the gutta percha may harden.

Most of the factories pass the hose, upon its leaving the apparatus, through a narrow box, from 15 to 25 feet long, supplied with running cold water.

Practical results have proved this length to be sufficient to cool off the hose so that it will retain its shape.

If hose is to be manufactured of such a length that one charge of the cylinder does not furnish sufficient material, the action of the piston may be stopped when the material in the cylinder is nearly exhausted, and the latter filled anew. The mass is then heated to the necessary degree and the labor continued. Hose more than 975 feet long has been manufactured in this manner.

Only very recently, machines have been constructed which permit the manufacture of hose of any desired length. From the manner in which they work, they may be designated as hose-forging machines.

A section of hose of a certain diameter and several metres long is prepared with the previously-described apparatus. A solid core of a suitable length is inserted in this section, and both are placed in a press, the lower half of which consists of a semi-cylindrical piece of metal corresponding with the outer diameter of the hose. The upper half of the press supports a piece of the same form as the lower, so that both together form a cylinder having a diameter equal to the outer diameter of the hose. The two halves of the cylinder are hollow and can quickly be heated by super-heated steam or hot air to the temperature at which rubber is vulcanized.

When the section of hose has been sufficiently

heated, the cylinder is opened, the core withdrawn, and a new section of hose pressed out from the first apparatus, which is then treated in the same manner. As the heating process always requires considerable time, the press cylinder may be refilled in the meanwhile, and, it will be readily understood, that hose of any desired length can be manufactured in this manner.

By a slight modification, the press used for the manufacture of hose may also be employed for preparing solid articles of gutta percha.

For this purpose, the front of the cylinder is provided with a pipe to which is fitted the open end of a metal mould, the hollow part of which corresponds with the form the article is to have. The mould must consist of several pieces, so that it can be taken apart and the contents removed, and, besides, must be provided with an opening through which the air contained in it can escape.

In order to form articles in this manner, the mould is heated to from 86° to 104° F., and then fastened to the pipe, and the softened mass of gutta percha is forced by a strong pressure of the piston through the pipe into the mould, this being continued until the mass makes its appearance through the air-hole. The mould is then removed and allowed to stand until the gutta percha contained in it is cooled off and hard. It is then taken apart and the small cylinder, which has been formed by the mass passing into the air-hole, cut off.

Gutta percha threads. Gutta percha being con-

verted into a very plastic mass when heated, threads of any desired dimensions can be readily prepared from it, rolls as well as presses being used for the purpose.

For pressing threads an apparatus closely resembling the one used for round rubber threads is employed, but the cylinder into which the gutta percha, previously heated to 212° F., is brought must be surrounded by a steam jacket to maintain this temperature in the cylinder.

To prevent the operation from being interrupted and to make it possible to obtain the gutta percha in the form of coherent threads from the narrow tubes, great care must be had in filling the cylinder so that the mass is compact and contains no spaces filled with air, as this would cause the thread to break. The simplest way of avoiding this is to bring the softened gutta percha into a cylinder of the same diameter as the press-cylinder. The mass is solidly pressed into this, and the cylinder of gutta percha thus formed, is then transferred to the press-cylinder.

The other parts of the apparatus are arranged in the same manner as in the one used for manufacturing rubber threads. A number of endless cloths are also used, over which the threads are carried, so that they may cool off and harden, but they need not be as long as those used in the manufacture of rubber threads. The best plan for cooling them off quickly is to use a powerful ventilator, throwing out a strong current of cold air. Dusting

with powdered talc is superfluous, as gutta percha loses all stickiness when cooled off to a certain degree. It is best to wind the finished threads upon rollers of considerable diameter, as, when this is done, it is easier to stretch them straight again in case this becomes necessary.

For manufacturing threads by rolling, the gutta percha must first be converted into a band somewhat thicker than the diameter of the threads which are to be cut.

The rolls used for this purpose are so constructed that half cylinders are cut in each, and the grooves, formed in this manner, stand so close together that their edges touch each other and form cutting edges. The rolls are placed over each other in such a way that two grooves fit exactly together and form a circular groove.

The band to be cut into threads is heated to 212° F. immediately before it is passed through between the rolls, and is carried to them over a plate of polished steel. The threads are then cooled off in the same manner as has been described.

By using suitably cut rolls elliptic, as well as polygonal, threads can be prepared in this manner. The principal point in arranging the rolls is to see that the grooves in the two rolls fit exactly together, as the threads, if this is not the case, will not acquire the desired form.

Coating wires with gutta percha. Of all the industrial applications of gutta percha, none is of greater importance than the coating of wires with it, as on

this depends the establishment of submarine telegraph lines, there being no other body suitable for this purpose which is such a non-conductor of electricity. Many comparative experiments have proved that a wire becomes insulated by simply allowing a coat of an ordinary gutta percha solution to dry upon it. As the coating not only secures complete insulation, but also protects the wire against the action of sea water, it may be said without exaggeration, that if gutta percha and its properties had not been known, submarine telegraph lines would perhaps never have been successful.

Insulation of telegraph wires by coatings of gutta percha demands attention to two very important conditions: The wire must lie exactly in the centre of the cable or cylinder, and the covering must be perfectly continuous, as the smallest crack would allow the sea-water to enter, and eventually destroy the insulation.

As the manufacture of telegraph cables is a special and limited branch of the industry, requiring large plants, it has been thought best not to enter very fully into the discussion of the subject, but confine ourselves to the description of the process of coating wire with gutta percha, large quantities of such wire being used in the manufacture of electric and magnetic machines.

The apparatus used for the purpose consists of a cylinder containing the gutta percha which has been softened by heat and is pressed forward by a piston.

The soft mass passes out of an opening which determines the thickness of the gutta percha cylinder. Below this opening is a die of metal, with a hole just wide enough to allow the wire to be coated to pass through without much friction.

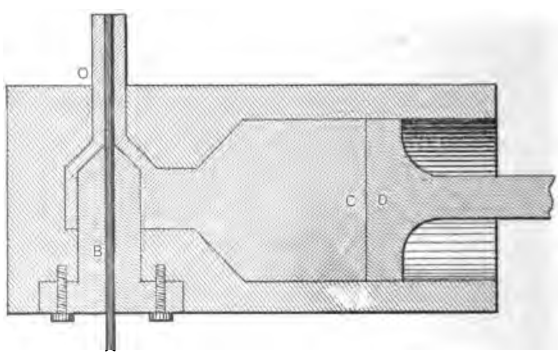
When the piston which acts upon the softened material presses forward, a cylinder of gutta percha is pressed out of the respective opening, and this, on account of the strong friction, carries the wire with it and incloses it entirely.

As the material must be heated so far that it can be pressed out of the small opening without the use of too much power, provision must also be made for sufficiently cooling the mass off before it is wound upon a drum. All that is necessary in this case, is to carry the wire through a channel 10 to 15 feet long, which is kept constantly filled with water, and then to wind it upon a large drum in such a manner that the separate windings lie alongside each other.

The accompanying illustration (Fig. 21) shows such an apparatus of the most simple construction. C is a cylinder containing the softened gutta percha; D is the piston by which it is pressed forward; B is a metal cylinder in the bore of which the wire sits. This is exactly opposite to the opening, O, through which the gutta percha is pressed. The wire which is to be covered with it is wound loosely upon a drum, and is drawn forward in consequence of the high pressure which the compressed material exerts upon it.

If several wires coated with it are to be formed into one cable, several such dies of metal in which the wires sit are fastened to the cylinder from which the gutta percha is pressed. The wires which are to be formed into one cable are passed through a cylinder while they are still warm, so that their coatings adhere to each other. The diameter of the

FIG. 21.



cylinder should be such that the wires, in passing through it, are gently pressed against each other.

But a simple coating with gutta percha does not suffice for cables which are to be immersed in water or to be laid underground. In such a case it serves only for insulating the wire. The cable which has been formed by joining the insulated wires together is generally covered with Manila hemp. A layer of gutta percha is applied to this and the operation repeated several times.

To protect the cable from being gnawed by animals, it is covered with galvanized iron wire, which

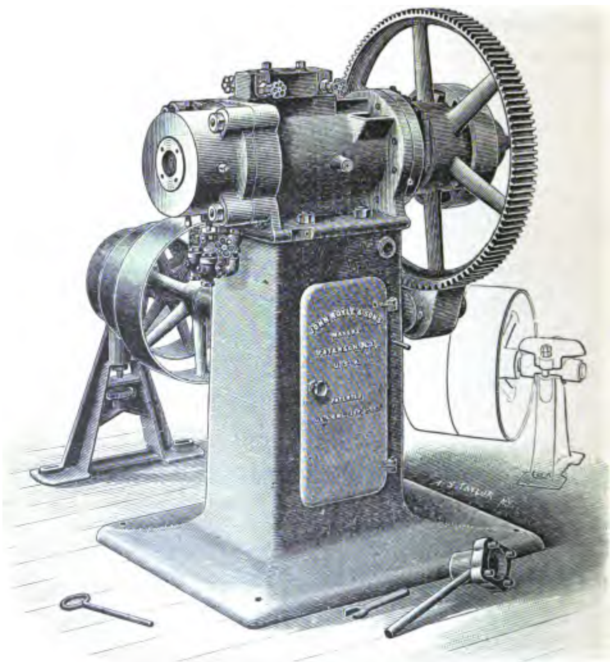
also receives a coat of gutta percha to protect it against rust. Large cables are generally prepared in such a manner that six copper wires coated with gutta percha lie around a centre wire, which is also coated, the seven wires together with their coatings forming a cylinder having a diameter of from 0.31 to 0.39 inch.

However, long submarine cables must be still further secured against breaking, and for this purpose are covered with suitable material—Manila hemp, galvanized iron wire, etc.—until they have a diameter of 1¼ to 1½ inches.

Fig. 22 shows a machine for insulating electric wire and cables, manufactured by John Royle & Sons, Paterson, N. J. In operation, the wire or cable enters the machine at the back and, passing through the bore of the thrust-bearing, enters the stock worm, which is bored through, the opening terminating at the forward end of the worm at a point precisely opposite to a corresponding opening in the bridge holding the guider. The guider is of the customary form, and conducts the wire to the die in the usual manner. The guider, when once set ready for operation, is fixed centrally to the axis of the machine, and cannot be turned or moved in any direction, all adjustments being made with the die, which is of compound form, consisting of a secondary holder and a die of the usual form, the secondary holder being threaded so as to screw into a die-holder slightly altered from the regular pattern. This arrangement permits of the die being

adjusted both sideways and lengthwise; sideways, by means of set-screws bearing on the circumference of the die-holder; and lengthwise by means of the secondary holder, which, by reason of its

FIG. 22.



threaded stem, can be run backward and forward at will. This method of adjustment will be found, in practice, extremely effective. It is simple and easy of operation, the adjusting movements being directed and depending merely on one piece, not on a combination of movements as heretofore.

In straight-delivery machines, it is important that cables, in passing through, be prevented from coming into contact with the stock-worm, the rotary movement of which might have a tendency to loosen the strands. To prevent any trouble of this sort, the bore of the stock-worm is lined with a fixed steel tube, which passes through the entire length of the thrust-bearing and cylinder and terminates at the guider. This arrangement not only prevents the movement of the stock-worm from being communicated to the cable, but also effectually protects it from contact with the insulating compound before it reaches the die.

Owing to the nature of the compounds used, insulating work is extremely severe, subjecting the machine to heavy strains, the back-thrust being, at times, particularly strong. To provide for all contingencies, a thrust-bearing has been designed entirely unique in its application to machines of this character and possessing features which fit it peculiarly to this class of work. It consists of a series of parallel grooves, extending from the termination of the stock-worm to the driving gears, into which is fitted a corresponding series of rings, which surround the shank of the stock-worm. The stock-worm extends back beyond the cylinder, where it is keyed into the inner portion of this bearing, which, in turn, extends back beyond the driving gear, where it terminates in a bonnet which covers the end of the bearing, and, passing forward over the hub of the driving gear, serves as a medium for transmit-

ting power from the driving gear, through the thrust-bearing, to the stock-worm. Owing to its massiveness there is no danger of this bearing giving way under any pressure that may be brought to bear on it in actual service; and, to prevent heating, carefully selected anti-friction metals are used on the bearing surfaces and ample means provided for such lubrication as may be necessary.

Vulcanization of gutta percha. As has been previously mentioned, attempts have been made to mix gutta percha with sulphur and subject it to the same processes by which vulcanization is brought about in rubber. However, these attempts resulted in complete failure, the good and characteristic qualities of gutta percha being destroyed by this process, without imparting to it new properties which would render it suitable for any known purpose. For the sake of completeness, a few of the processes recommended for vulcanizing gutta percha are here given.

A much smaller quantity of sulphur is required for this purpose than for rubber, since the use of an excess of it would result in a brittle product. However, pure sulphur alone is seldom used, preference being given to sulphur in connection with metallic sulphides, or to chloride of sulphur. The following mixture has been recommended:

Gutta percha . .	48 parts	by weight.
Sulphur . .	1 part	"
Sulphide of antimony	6 parts	"

The substances are mixed in a manner similar to that which has been described for preparing vulcanized rubber. The gutta percha is vulcanized at a temperature of from 257° to 302° F.

The process of vulcanizing gutta percha with chloride of sulphur is as follows: The cleansed gutta percha is cut up into shreds and dissolved in carbon disulphide so as to form a stiff solution of about the consistency of syrup. To this solution 2 to 15 per cent. of chloride of sulphur is added, according to the required extent of vulcanizing, 10 per cent. rendering the gutta percha hard and horny, and it does not become soft even if exposed to a temperature of 212° F. The hardness increases in proportion to the quantity of chloride of sulphur used. Sheets are vulcanized by repeated dipping. For coating articles with vulcanized gutta percha a stiff solution in carbon disulphide is used. The articles are brushed over with the solution and, when dry on the surface, are plunged into a solution containing 5 to 10 per cent. of chloride of sulphur to 100 parts of carbon disulphide.

CHAPTER XII.

BLEACHING OF GUTTA PERCHA.—GUTTA PERCHA COMPOUNDS.

GUTTA PERCHA can be thoroughly bleached without suffering thereby a chemical change, as is the case with rubber; and its great indifference towards chemical agents, and the fact that by bleaching it loses none of its physical and chemical properties, make it an invaluable material in dentistry, and the more so as a color can be given to it which so closely resembles that of the human gums as to defy detection.

As bleaching agents, animal charcoal or chloroform may be used. If the latter is employed, the commercial gutta percha is cut up into small pieces, and twenty times the quantity of chloroform is poured over them. When solution is complete, which will be the case in about three or four days, about half a pint of water is added. The vessel containing the solution is then thoroughly shaken and allowed to stand quietly until the contents have become separated into two distinct layers, the lower one of which consists of a solution of pure gutta percha, and the upper one of the water and the foreign substances which had been mixed with the gutta percha.

The clear solution is then draw off by means of a

siphon into a porcelain basin. This is placed in a copper still and surrounded with water. The still is then closed and heated, and the chloroform distilled off.

The purified gutta percha remains in the porcelain basin in the form of a vesicular mass, which can be formed into plates and small sticks by softening it in hot water and by mechanical treatment. While a purified article is obtained in this manner, it is not entirely decolorized, as it always shows a weak yellowish or brownish color.

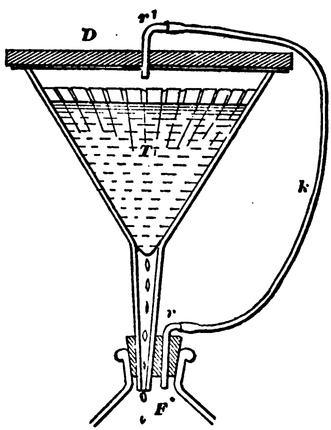
An entirely decolorized, pure white product may be obtained as follows: Purified gutta percha is dissolved in twenty times the quantity of carbon disulphide. The solution is clarified by allowing it to stand quietly, and is then filtered through finely powdered animal charcoal. But on account of the great volatility of the solvent, it is necessary to use a suitable apparatus for filtering.

An apparatus of this kind, of simple construction, and performing excellent service, is shown in the accompanying illustration (Fig. 23). It consists of a large bottle, *F*, either of glass or tin. This is hermetically closed by a cork with two holes. The neck of the glass funnel, *T*, the upper rim of which is ground smooth, is placed in one of the holes, and a glass tube, *r*, bent at a right angle, is fitted into the second hole. A thick wooden lid, with a ring of rubber on the lower side, is placed upon the funnel, thus closing it air-tight. In the centre of the lid is fitted a glass tube, *r′*, also bent at a right

angle, which is connected with the tube *r* by a rubber hose, *k*.

The funnel, the neck of which is closed by a stopper of cotton, is filled about two-thirds full with animal charcoal. The solution to be filtered is poured upon this, the lid is placed in position, and must be removed only for the purpose of pouring more solution into the funnel. The air in the bot-

FIG. 23.



tle *F* is displaced by the solution dropping into it, and escapes through *r*, *k*, and *r'* into the funnel *T*, where it absorbs the vapor of the solution, *but absorbs nothing more after it is once saturated.* While evaporation goes on constantly when an open funnel is used, it is entirely checked by using this apparatus. To obtain the last remnant of the solution retained by the animal charcoal, a quantity of carbon

disulphide, about $\frac{3}{4}$ inch deep, is poured upon the animal charcoal, which will remove all the solution from it.

The solution filtered through animal charcoal is almost colorless, and after the evaporation of the carbon disulphide an entirely white mass is obtained which can be colored with the most delicate coloring matter. To remove the last traces of the solvent the mass is heated for some time at 212° F.

Solutions of gutta percha bleached in this manner are entirely colorless, and when spread upon glass plates furnish a coating resembling a film of collodion, but have the advantage of possessing greater solidity and tenacity. As the preparation of bleached gutta percha is rather complicated, it is scarcely employed for any other but dental purposes, although an excellent use could be made of it for ivory compositions, though at present such masses can be prepared more cheaply with the assistance of celluloid.

Cattell's bleached gutta percha is made by dissolving cleansed gutta percha in solvents requiring heat, as coal-tar naphtha and its rectified products, turpentine, and rosin-spirit, or solvents requiring no heating, as chloroform or carbon disulphide. In using the first class of solvents, 1 oz. of alcohol, holding in solution 30 drops of glycerine to the gallon, is agitated in a closed vessel, together withh the solvent and gutta percha, for an hour or more, until sufficiently defecated or decolorized, when it is mixed with a little alcohol and glycerine, to precip-

itate the gutta percha. The solvent is recovered by distillation. The alcohol or similar agent removes the oxidized portions of the gutta percha, resins, etc., and leaves the pure gutta percha colorless.

The product thus obtained can be mixed with coloring pigments for the production of useful or ornamental objects. Oxide of zinc, vermilion, and similar compounds can be used, but not compounds or oxides which represent a saturated or high degree of oxidation. Gutta percha by strong oxidation gives rise to formic acid.

Gutta percha compounds. Gutta percha, similar to rubber, possesses the capacity of combining with a variety of substances and on account of its softening when exposed to heat, the preparation of such compounds presents little difficulty. By choosing suitable substances, compounds resembling leather, wood, whalebone, horn, and even stone can be obtained.

Compounds of rubber and gutta percha are largely used in galvanoplasty for the production of overlapping moulds of one piece. By itself, gutta percha is an excellent material for taking impressions of coins, medals, etc., it being only necessary to heat a sheet of it until soft, place the coin or medal upon it and subject the whole to strong pressure, leaving it in the press until cold. The gutta percha sheet then shows the negative picture of the coin or medal in its finest details, and such moulds have the advantage over those of plaster of Paris that they can be repeatedly used for making copies.

However, for over-lapping matrices or moulds a mixture of rubber and gutta percha has to be used, as besides plasticity when heated, they must possess a high degree of elasticity so that when pulled from the copied object, the mould assumes the same shape as when upon the object.

The proportion of rubber and gutta percha best adapted for this purpose can only be ascertained by special experiments. A more elastic (richer in rubber) mixture must be used for deeply-cut models, which are to be copied (high reliefs) than is necessary for copying a less projecting article (low relief). The best plan for mixing rubber and gutta percha into a homogeneous mass is to pass sheets of them through between heated rolls revolving at unequal velocities, to cut up or fold up the sheet thus formed, to again pass this through between the rolls, and to repeat this operation until an entirely homogeneous mass has been formed.

Gutta percha and rubber compound for machine belts. Compounds of rubber and gutta percha in suitable proportions combine great tenacity and solidity with a certain degree of elasticity, and can therefore be advantageously used for the manufacture of machine belts. Although such belts are rather expensive, they are cheaper in the end, as they are almost indestructible, and besides can be readily repaired. A compound very suitable for this purpose consists of:

	Parts by weight.
Gutta percha	70 to 75
Rubber	30 to 25
Sulphide of antimony . .	5 to 4
Sulphur	2 to 1

To obtain as intimate a mixture as possible, it is advisable to weigh the rubber and gutta percha in the form of shavings, to mix them thoroughly together and form bands in the manner already described. These bands should be rolled until they are entirely homogeneous, the sulphur and sulphide of antimony being incorporated with them at the same time.

The mass, when finished, is formed into a block, and this is passed through between the rolls at a rather low temperature, and is gradually changed into a band corresponding in width with that of the belt to be manufactured. When the thickness of this band nearly approaches that which the belt is to have, the temperature is lowered so much that the band can be forced through between the rolls only at the expense of great power, to make the mass as compact as possible.

The edges of the belt are then trimmed, and it is covered on one side with a linen or cotton cloth, and wrapped loosely round a wooden roller in such a manner that the cloth forms a layer separating the windings of the belt from each other, since if this were neglected the mass would fuse together during the heating process. It is then brought into the heater, and the temperature,

especially for thick belts, must be raised to 320° F. When removed from the heater, it is taken from the wooden roller, smoothed, and polished by being passed through between the rolls of a calender.

Hard gutta percha compounds. Various admixtures are used for this purpose, they being nearly the same as mentioned for rubber, including earths, oxides and finely pulverized minerals. While the object of adding some of the ingredients is to give weight or color to the mass, many have no other use except economy in making the necessary bulk.

Whiting, white pipe-clay, magnesia, oxide of zinc, washed barytes or artificially prepared sulphate of baryta are used for white, or rather yellowish colored articles. If they are to be of light weight, it is advisable to use magnesia; for heavy objects, sulphate of baryta is the best.

On account of the brown color of unbleached gutta percha, the compound prepared with white materials will not show an entirely white, but always a more or less yellowish-brown color. If it is desired to obtain entirely white compounds, bleached gutta percha has to be used.

Ferric oxide (colcothar) can be used as a component for reddish-brown compositions; powdered pyrolusite for dark-brown masses; and black compounds may be prepared by incorporating bone-black, etc., with the gutta percha.

The total weight of the added ingredients may be greater than that of the original gutta percha, without destroying its plastic property, or prevent-

ing its being moulded into any desired shape. But such compounds will always show some degree of brittleness, and for this reason their use is limited to such articles as are not to be exposed to shocks, as door handles, escutcheons, ornaments for frames, etc.

For articles exposed to shocks, the foreign admixtures must not amount to more than from 25 to 30 per cent. of the weight of the gutta percha, and from such masses may be manufactured many of the utensils for daily use which were formerly constructed of leather, tin or wood.

To hide the peculiar and not agreeable odor of gutta percha, sweet smelling substances should be mixed with it; essential oils having frequently been used for this purpose. While these completely disguise the odor of gutta percha, they possess the disadvantage of gradually volatilizing. It is, therefore, advisable to choose substances which will retain their perfume for a long time; benzoin, tonka beans, and orris root can be recommended. Of benzoin, 4 per cent. of the weight of the mass is sufficient to make the odor an agreeable one; of tonka beans ½ per cent. is more than sufficient; if orris root (the root of *Iris florentinæ*) is used, about 10 per cent. will be required, as its perfume is not very strong. Fine shavings of sandal wood or of American juniper (*Juniperus virginiana*) may be used instead of orris root.

Compounds of gutta percha and wood. For many years, admixtures of finely pulverized cocoa-nut shells have been used in gutta percha compounds,

giving to them the properties of wood. The shells are powdered in stamp mills, and the resulting powder is sifted and incorporated with the gutta percha in the usual manner.

But powdered wood and sawdust of hard woods can also be used for this purpose. The sawdust is ground and sifted so as to form fine flour. It is, however, absolutely necessary to thoroughly dry the powdered wood before mixing it with the gutta percha, and it may be further recommended to coat the plates, made from such compositions, with a gutta percha varnish.

Compounds of gutta percha and wood can, like wood, be worked by means of the saw and turning lathe, and can be very advantageously used for covering wooden articles. But for the wood and composition to adhere tightly to each other it becomes necessary to frequently saturate the first with linseed oil, before the compound is laid on, to prevent it from absorbing atmospheric moisture. If this precaution is neglected and the wood should become damp, the compound would fall off in consequence of the expansion of the wood.

By coating two boards saturated with linseed oil with a gutta percha and wood compound, placing them cross grained upon each other and heating sufficiently to soften the gutta percha, and then subjecting them to a heavy pressure until cold, a tablet of extraordinary tenacity and resistance, exceeding those of the hardest woods, will be formed.

Sorel's gutta percha compounds. The substitutes for rubber and gutta percha which were introduced by Sorel, must actually be considered as gutta percha compounds, the gutta percha being mixed with pitch, rosin, lime, and potter's clay. The best of Sorel's compounds consists of:

	Parts.
Rosin	2
Pitch or asphaltum	2
Rosin-oil	8
Slacked lime	6
Water	3
Potter's clay	10
Gutta percha	12

The purpose of the rosin-oil in this composition is evidently to dissolve the pitch and rosin, and the admixture of lime is very likely for the purpose of effecting a combination between the acids of the rosin and the lime. The potter's clay is introduced into the composition as an indifferent substance to increase the weight of the mass, and can, therefore, be replaced by other indifferent substances (chalk, magnesia, colcothar, etc.), or can be entirely left out. In the latter case a compound is obtained which, in regard to its properties, approaches that of pure gutta percha.

The manner of preparing the composition is as follows: The rosin, pitch, and rosin-oil are stirred together in a boiler until complete solution has been accomplished, which can be accelerated by heating

the substances. The lime and water mixed together to a paste are then added, and finally the gutta percha and potter's clay, but the latter only when the gutta percha has become fluid. More water is added to the mass, and it is heated to the boiling point of water, 212° F., and then taken from the boiler.

Even if the work is carried on with the greatest care, it will be impossible to obtain in this manner an entirely homogeneous composition. To do this, it is necessary to pass the mass several times through between rolls. 5 per cent. of stearic acid or wax should be added to the composition for the purpose of making it entirely water proof.

Sorel varies his mixture to suit different purposes and claims that they can be substituted for pure gutta percha; but his compositions have not the great tenacity of the pure material, nor its indifference to chemical action, and cannot be advantageously used for articles liable to exposure to chemical agents. The following are some of Sorel's receipts for manufacturing gutta percha compounds:

	I.	II.	III.
	Parts.	Parts.	Parts.
Pitch	8	12	—
Rosin-oil	4	—	—
Coal tar	—	—	12
Slacked lime	6	6	6
Gutta percha	16	16	16

Rousseau's solutions of gutta percha and their use.

Gutta percha, to which linseed oil has been added, is heated in a suitable vessel over an open fire. Linseed oil generally absorbs one-tenth of its weight of gutta percha.

When a white cotton fabric is dipped into this solution it will be thoroughly penetrated by it, and, after it has become cold, will be of a yellowish color, transparent and very soft. Such material can afterwards be printed with all kinds of colors.

Whiting, ochre, lampblack, etc., may be added to the solution for the purpose of thickening and coloring it, which will also remove the peculiar odor of the gutta percha.

For lacquering leather, coating of taffeta and gauze, some copal varnish, to which the gutta percha imparts its softness and elasticity, must be mixed with the solution.

It can be mixed with all substances—gutta percha especially exerting no influence whatever upon oil paints.

Chatterton's gutta percha compound. This compound is employed for uniting the different coatings of gutta percha cores, and for cementing gutta percha to wood, etc. It is prepared as follows: Stockholm tar, $\frac{1}{5}$ part by weight, and about the same weight of rosin, are put into a jacketed vessel heated by steam, strained when melted and intimately mixed with $\frac{3}{5}$ part by weight of cleansed gutta percha in shreds or thin pieces. The whole is worked together by horizontal stirrers, fixed on a vertical shaft.

CHAPTER XIII.

RUBBER AND GUTTA PERCHA WASTE AND ITS UTILIZATION.

THERE will always be a certain amount of waste in manufacturing articles from rubber and gutta percha, no matter how carefully the work may be done, and the materials being expensive, means should be found of turning this waste to account.

A distinction must be made between waste from pure and from vulcanized rubber, and care should be observed to keep them separate, because while the working-up of one kind of waste is quite simple, and there is but little difficulty in deciding how it can be utilized to the best advantage, a mixture of different kinds of waste frequently presents considerable difficulty in working, and besides a mass of little value is finally obtained which is only fit for articles of very ordinary quality.

The utilization of pure crude rubber waste is a very simple matter, it being only necessary to form it into lumps and to pass these again through between the rolls. The material thus obtained frequently possesses a higher degree of plasticity than that originally used.

Waste of vulcanized rubber is comminuted as much as possible by mechanical means, a grating

apparatus or hollander being generally used for the purpose, and then mixed with pure rubber cut up into very small pieces. The materials are then mixed, which is done by repeatedly passing the heated mass through between rolls, while at the same time sufficient sulphur is added to vulcanize the pure rubber to the same extent as the waste. The mass must be worked until it is so uniform that the separate parts cannot be distinguished from each other by the naked eye, and then articles may be fashioned from it in the usual manner, which are finally vulcanized by subjecting them to the heating process.

According to another process the waste is first cut up into small pieces. These are boiled for several hours in caustic soda for the purpose of desulphurizing them. But this can only be done in a satisfactory manner when the pieces are very small, and the boiling is continued for a sufficiently long time.

In order to knead the waste, after it has been boiled, together with rubber, it is only necessary to continue the boiling until the pieces again possess the property of sticking together when heated.

It is claimed that by Aco's process, not only waste of ordinary vulcanized rubber can again be utilized but also that of hard rubber. 220 pounds of waste are treated in a closed vessel for two hours with a mixture of 22 pounds of carbon disulphide, and 495 pounds of spirit of wine. It is claimed that by this manipulation the mass becomes sufficiently softened to allow of its being mechanically treated by masticating and kneading.

If this process could be used just as described, it would surpass all others in regard to simplicity. But the results of many experiments have always been that many difficulties arise which can scarcely be overcome, and especially when hard rubber is mixed with the waste.

If the work is to be done by this process, it is at least necessary to sort the pieces of hard rubber from the waste and to treat them by themselves. But the simplest manner of utilizing hard rubber waste is to melt it and work it into varnish, as described in a previous chapter.

Another method of utilizing vulcanized rubber waste is as follows: The waste is comminuted as much as possible and is then exposed to a temperature of 572° F., until a plastic mass has been formed. Heating is effected by steam which is passed through a cylinder containing the small pieces of waste. Eleven pounds of the plastic mass obtained are mixed with two ounces of palm oil, six ounces of sulphur and two pounds of white lead or magnesia, chalk or oxide of zinc. Articles moulded from this mass are subjected to the heating process.

In conclusion, Newton's method may be mentioned. The waste is treated in a well-closed vessel with camphene. It is allowed to remain in the vessel for fourteen days, and is then heated to about 158° F. to complete the action of the camphene. The greater portion of the solvent is then distilled off, and the tough mass remaining in the still

worked up. However, if the vulcanized rubber has been prepared with the assistance of metallic sulphides, the result is not satisfactory.

However, no matter what process may be used for the production of rubber mass from waste of vulcanized or hard rubber, the resulting product never possesses the properties demanded of a first-class material. It is therefore best to work it into hard rubber articles, of course after it has been comminuted in a suitable manner and mixed with pure rubber and sulphur. The disparity of quality is not so perceptible in these articles as in those of vulcanized rubber, which must possess a high degree of elasticity at all temperatures.

Waste of gutta percha accumulating in the factory is more valuable than that of rubber, because it being as a rule pure, not mixed with foreign substances and not vulcanized, it can at once be utilized. On the other hand, the value of old material is dependent on the degree of oxidation it has undergone and the chemical influences to which it has been exposed by the action of acids or very high temperatures. Such old material is frequently almost worthless, while, when it is only oxidized, it can be again made available by treatment with hot water to which caustic soda has been added, or with benzene or turpentine, by washing, kneading and mixing with fresh virgin material.

CHAPTER XIV.

EXAMINATION OF RUBBER ARTICLES.

VERY few of the articles found in commerce are made of pure rubber, most of them containing abundant additions of other less valuable inorganic or organic materials, such as chalk, gypsum, heavy spar, oxides of zinc and iron, cork meal, oil, paraffine and similar substances. These additions are made to such an extent that many articles may be designated as an admixture of rubber combined with mineral powder. It is difficult to decide how far these admixtures are to be considered serviceable or as adulterations, since the articles, according to the demands on them, must consist of pure material or must receive various additions. Thus, according to Kissling, a packing ring for steam pipes should have a different composition from a gas tube, or a man-hole ring for a compressed air receiver. A valve which has to resist the action of strong mineral acids must be made of a different mixture from a so-called oil-resisting rubber article. However, there is still considerable confusion regarding the question how large the percentage of rubber in a technical article intended for one or the other purpose must be.

The determination of the specific gravity affords

a clue to the extent of the admixtures. Since pure rubber and pure gutta percha are specifically lighter than water, massive articles of pure materials will float upon water. By the addition of the sulphur required for vulcanizing, the specific gravity is somewhat increased, but only in so far that the articles, if they contain no other admixtures, still float upon water, or are only slightly specifically heavier than water, while by the addition of mineral substances the specific gravity is considerably increased, as shown by the following determinations:

Specific gravity.	Content of ash, per cent.	Quality of gas tubes.
0.98	0.66	very good tubes.
0.99	2.83	
1.05	2.00	ordinary tubes.
1.20	19.00	gray-black, inferior quality.
1.17	24.60	gray-black, cracks readily, but elastic.
1.20	25.00	
1.26	34.30	gray, very bad.
1.52	38.60	red, becomes brittle in a short time; very bad.

The ash consisted of zinc oxide, chalk and ferric oxide, the latter predominating in the red tubes.

Although according to these figures the specific gravity alone is not sufficient for the determination of the quantity of admixtures present, it throws enough light upon the subject so that the question whether the article has been artificially weighted to a smaller or greater degree can be accurately answered, and for this purpose an approximate deter-

mination suffices. This determination is made by placing the material, cut up in small pieces, in water to which a sufficient quantity of a readily soluble salt is added until the solution has acquired such a density that the pieces of rubber, when stirred, neither sink to the bottom nor rise to the surface, but float in the fluid in all positions. The fluid then has the same density as the rubber to be tested. It is only necessary to filter the fluid through a dry filter and to determine the specific gravity of the filtrate by means of a hydrometer.

An accurate examination of rubber articles presents great, partly insurmountable, difficulties. Even if the admixed organic snbstances are temporarily left out of consideration, many complications appear in the determination of the mineral constituents. For instance, if zinc oxide has been used as a filling material, by ignition a reduction and volatilization of metallic zinc may take place; silicates containing water, for instance, talc, when ignited, yield their water, and the content found is too small; the sulphur may form metallic sulphides or sulphates; carbonates, white lead, chalk, etc., yield their carbonic acid entirely or partly.

For determining the total quantity of filling substances, it is best to dissolve the rubber in petroleum and to examine the residue, whereby, however, it has to be taken into consideration that by this treatment a portion of the sulphur passes into solution.

For the examination of pure rubber, vulcanized with sulphur alone, the determination of sulphur

suffices in order to find the quantity of sulphur present. Unger gives directions for examining articles vulcanized with pentasulphide of antimony, which is very frequently a varying mixture of pentasulphide of antimony with free sulphur and sulphate of lime, the content of free sulphur which can be extracted with carbon disulphide amounting to from 6 to 30 per cent., and that of sulphate of lime to from 9 to 62 per cent. It may also be remarked here that not only commercial pentasulphide of antimony contains sulphur which can be extracted with carbon disulphide, but it has also been found, by Wilm, in varying quantities in preparations of pentasulphide of antimony made in various ways and with the greatest care. In examining such articles the determination of the total sulphur of the antimony and calcium must be taken into consideration.

Determination of sulphur. Weigh off 0.5 to 0.55 gramme of the sample and cut it up into about 100 small pieces. Prepare a mixture of 12 grammes of finely pulverized cupric oxide and 2 grammes of chemically pure, anhydrous carbonate of soda. Then place upon the bottom of a porcelain crucible a layer of pure cupric oxide, and upon this a layer of the mixture. Press into the latter about 8 pieces of the rubber so that they do not touch each other and are about 3 to 4 millimeters from the sides of the crucible. Upon this place another layer of mixture and distribute in it in the same manner 10 pieces of rubber, and continue thus until all the

rubber has been brought into the crucible. Cover the last layer slightly with mixture and pure cupric oxide. The crucible should not be excessively large and the pieces of rubber should be as uniformly as possible distributed. Cover the porcelain crucible with a platinum lid, place it in a platinum crucible and heat at first very slowly, whereby the rubber melts and penetrates the surrounding mass. Heating is continued for some time, but no gray smoke should escape, and only a peculiar odor reminding one of fennel should be diffused. After moderate heating for about half an hour, the crucible is brought to a red heat for about 10 minutes, when it is allowed to cool, and the contents are dissolved in hydrochloric acid with an addition of nitric acid.

The fluid is reduced to dryness in the water-bath whereby antimonic acid in an insoluble form is separated. The residue is taken up with about 600 cubic centimeters of water and, after filtering, compounded with barium chloride to precipitate the sulphuric acid, which is determined in the usual manner.

According to Henriques, correct results are not obtained by fusing with soda and saltpetre, because with too small an addition of saltpetre, sulphur is volatilized with the escaping gases, or with larger quantities explosions readily occur. To avoid both, it is recommended to bring about 20 cubic centimeters of fuming nitric acid into a small porcelain dish, which is covered with an inverted funnel, and introduce gradually 3 to 4 grammes of the rubber

in fine shreds. A violent evolution of gas takes place and the rubber is destroyed. When decomposition is complete, the excess of nitric acid is removed by evaporation upon the water-bath, and the residue is mixed with about 4 grammes of a mixture of 3 parts potassium nitrate and 4 parts soda, and fused at a gentle heat. The residue is taken up with water, and after adding hydrochloric acid, evaporated to dryness, to separate silicic acid and, in the solution filtered from it, the sulphuric acid is determined. In the presence of lead or barium combinations, sulphate of lead or of barium is found with the silicic acid and has to be separated from it.

Determination of antimony. Put in a porcelain crucible about $1\frac{1}{2}$ grammes of the sample cut up in very small pieces, together with 10 grammes of crystalized calcium sulphide. Heat, at first gently, and when foaming ceases more vigorously, and finally bring to a gentle red heat, stirring occasionally with an iron wire. After cooling take up the fused mass with water, filter off separated coal, etc., filter and super-saturate the filtrate with hydrochloric acid, whereby a mixture of antimonious sulphide and sulphur is precipitated. This mixture is collected upon a weighed filter, dried at 212° F., weighed, and in a portion taken from the filter and weighed, the antimony is determined.

Determination of calcium. Ignite the rubber in an open porcelain crucible until a white ash remains behind. This is heated with hydrochloric acid, the

resulting fluid compounded with an abundant quantity of hot water, supersaturated with ammonia, whereby antimonious oxide is separated, after filtering precipitated with oxalic acid, and from the separated calcium oxalate the quantity of calcium is determined.

In a sample of rubber, Unger found by this method:

Sulphur . . .	5.72	per cent.
Antimony . . .	6.813	per cent.
Calcium . . .	0.3046	per cent.

The calcium is calculated to sulphate, the antimony to pentasulphide, and the remaining sulphur taken into account as such. According to this the sample examined would contain:

11.335	per cent. pentasulphide of antimony	(with 4.542 per cent. sulphur).
1.310	per cent. gypsum ($CaSo_4.2H_2O$ . .	(with 0.244 per cent. sulphur).
0.934	per cent. sulphur	(with 0.934 per cent. sulphur).
86.401	per cent. rubber	(with 5.720 per cent. sulphnr).
100.00	per cent.	

It is doubtful whether in rubber vulcanized at a high temperature, crystallized calcium sulphate with 2 molecules of water is present, and it would be more correct to take gypsum in an anhydrous state into the calculation.

From the result of the analysis, Unger calculates that the mass to be vulcanized consisted of rubber, 100 parts, and pentasulphide of antimony, 15.74, or perhaps more correctly, 16 parts, and that the pentasulphide used had the following composition:

Pentasulphide of antimony, 85.50 per cent.; gypsum, 9.63; free sulphur, 6.87.

To ascertain the nature of other mineral filling substances, a complete analysis of the ash has to be executed. With admixtures containing lead it must be taken into consideration that the sulphur is converted into sulphate of lead.

For the detection of admixtures of organic substances, such as cork meal, etc., it is advisable to subject thin sections previously swelled up as much as possible in carbon disulphide to a microscopical examination.

For the detection of a content of oily substitutes which are frequently mixed in larger quantities with rubber, Henriques recommends to boil, from six to eight hours, 2 to 5 grammes of the substance, cut up in small cubes, with about ten times the quantity of alcoholic soda solution which contains 6 to 8 per cent. of sodium hydroxide. Only a very small quantity of rubber is dissolved, but the total quantity of the oily substances, together with a portion of the sulphur, passes into solution, while a part of soda present enters into an insoluble combination with the sulphur.

III. BALATA.

CHAPTER XV.

HISTORY, OCCURRENCE AND USES OF BALATA.

LIKE gutta percha, balata is the inspissated milky juice of a few plants of the family *Sapotaceae*, which, however, belong exclusively to the genus *Mimusops*. It was formerly considered identical with gutta percha, but it is distinguished from it by sufficiently characteristic differences to assign to it a more independent position.

Balata became first known about 45 years ago, the first account of it being found in an article published in 1857, by Prof. Bleekrode, and in a communication made, the same year, by him to the Society of Arts. In these communications he designated balata as Sumatra gutta percha, and concluded that it was a product identical with that obtained from *Isonandra gutta*. In 1860, the Colonial Secretary of British Guiana forwarded to the Society of Arts a few specimens of balata collected by Van Holst in Berbice, which were later on turned over to the Kew Museum. The same society having offered a prize for the best substitute for gutta percha, received in February, 1864, other samples of balata from Sir William Holmes. In

his letter to the Secretary of the Society, Holmes states that at the International Exposition of 1862, he had exhibited about ½ lb. of balata, which later on had been handed over to Charles Hancock, who had expressed a very favorable opinion in regard to it. This sample was also sent to the Kew Museum, and the same institution received other samples as follows: from James Collins, 1868, from British Guiana; from Governor Longdon, 1874, from Trinidad, and from Im Thurm, 1882, from Demerara. In 1884, G. S. Jenman forwarded samples of balata, as well as balata milky juice, and of balata prepared by precipitation with alcohol.

The genus *Mimusops* is distributed over almost the entire globe, but thus far trees yielding balata are only known to occur in *America:* In the Antilies and Bahama Islands (West Indies), in Venezuela, British, Dutch and French Guiana, and a portion of Brazil; in *Africa:* On the west coast of the equatorial region, Abyssinia, Angola, Madagascar and Mauritius; in *Australia:* In Queensland and New Zealand. Hence the home of balata is in an entirely different location from that of gutta percha.

Mimusops Balata is the principal balata-yielding tree. It is indigenous to English, Dutch and French Guiana, Surinam, Barbadoes and the Antilles, Brazil (Amazon), Costa Rica. It is a large tree, with a trunk about 6 feet in diameter, and furnishes a wood much sought after as a building material. The Dutch name Paardenflesch (horse-flesh), is given on account of the wood being of the

color and having the appearance of horse-flesh. The bark is thick and rough, and the fruit is of the size of a coffee berry, sweet like a plum, and with a hard white kernel, which yields an oil bitter in taste. The leaves are glossy, oval and acuminated. The milk is drunk by the natives, and when diluted with water, used as cow's milk. The trees grow in groups, and in alluvial soil.

Besides *Mimusops Balata*, the following varieties of *Mimusops* which yield balata may be mentioned: *M. globosa*, *M. speciosa*, *M. Schimperi*, *M. Kümmel*; further *Lucumus* varieties: *L. gigantea*, *L. fissilis*, *L. lasciocarpa*, *L. laurifolia*, *L. procera*, and finally a few varieties of *Chrysophyllum*.

For obtaining the balata latex it is not sufficient to make simply incisions in the bark, as the milky juice of *Mimusops* is so thick and coagulates so rapidly that the incisions would soon be choked up.

In Venezuela the collectors formerly sawed the trees off near the foot, raised them upon props, and placed vessels under them for the collection of the juice which exuded from numerous incisions made scarcely a foot apart from each other. By this barbarous method about 7 to 13 lbs. of balata were obtained from a tree of medium size. At the present time hand-presses, by which the bark is subjected to strong pressure, are used. One press yields in an hour 9 to 13 quarts of juice which is equal to from 4 to 7 lbs. of dry balata. In Maturin, a region which embraces the Venezuelan provinces of Cumania, Barcelona, Guiana, and Isla Margarita, very large

trees are found from which by this process several hundredweight of balata are obtained. Hence this system of destruction is extraordinarily lucrative, and is so widely extended that, if continued, this source will soon be exhausted, notwithstanding the great abundance of balata trees in Maturin.

In Dutch Guiana, especially in Surinam, the trees are tapped. The bark, up to a height of 20 feet, is provided with incisions which are connected with each other and so arranged that the juice from one gutter runs into the other until it reaches the lowest one, where it is caught in a calabash, from which it is later on poured into a larger vessel provided with a handle, which is called "gooba." In this gooba the juice is carried to the settlement, and either sold as it is, or poured into shallow wooden evaporating dishes. As the water evaporates the surface hardens, and skins about $\frac{1}{4}$ inch thick are formed, which are removed and hung up over lines to drain and dry. This drying requires several weeks, since every balata skin presents a hard surface which retards evaporation. A gallon of juice yields 4 lbs. of dry balata. A tolerably skilled workman obtains about 4 gallons of milk a day, and a very skilled one up to 10 gallons.

In British Guiana the method of gathering balata is more rational as far as the preservation of the trees is concerned. Several longitudinal incisions are made in the trunk of the tree, and the bark between them is removed. The liber or inner bark, however, is left standing, which makes the

formation of new bark possible. The most suitable method is to remove and leave the bark standing in alternate squares. The bark removed is then pressed, a medium-sized tree yielding by this method about 2 lbs. of balata; but it must be taken into consideration that this operation can be indefinitely repeated, since every succeeding year the pieces of bark previously left standing are taken. The juice flows most abundantly during the rainy season, and it also coagulates more slowly during that period. The milk which is called, in British Guiana, "Purvio," is collected in wooden vessels, since iron vessels impart to it a blackish color, which depreciates the commercial value of the product.

Crude balata is gray, brown, or white-reddish with darker spots and veins; in appearance it resembles dry skins and it feels soapy to the touch. Gray balata comes into commerce also in blocks about 32 inches long and 16 inches wide, but red balata only in sheets $\frac{1}{8}$ to $\frac{3}{4}$ inch thick. The sheets show the shape of the vessel used for evaporating the juice. The commercial article contains, as a rule, few foreign bodies, and little bark. Lime is frequently added, especially more recently where the natives adulterate the juice by an addition or water, and then add lime to give the product the necessary consistency. At an average the quantity of impurities amounts to 10 per cent.

The balata from *Mimusops Balata* and *M. globosa* are especially valued since, besides their great

strength, they posses the property of being ductile only in a very slight degree, which makes them especially suitable for the manufacture of belts. They bring as high and even a higher price than gutta percha.

In his "Cantor Lectures on Gutta Percha," previously referred to, Dr. E. F. Obach gives valuable statistical data regarding the price and export of balata from British and Dutch Guiana. These data have been taken partly from government reports on the colonies and partly from communications of the Director of the Colonial Museum at Haarlem, as well as from a report of Mr. Churchill, consul at Paramaribo, to the Marquis of Salisbury.

For the period from 1885 to 1896, they are as follows:

Export from British Guiana.			Export from Dutch Guiana.		
Year.	Cwts.	Value £.	Year.	Cwts.	Value £.
1885	496	2213			
1886	606	2979			
1887	723	3498			
1888	2219	14069	1889	30	116
1889	3245	15625	1890	1502	7951
1890–91	2025	10078	1891	1882	11950
1891–92	1039	6807	1892	2375	15086
1892–93	2120	11296	1893	641	5424
1893–94	1832	8283	1894	2132	18047
1894–95	1867	11484	1895	2631	22281
1895–96	1424	8923	1896	2480	21000
Total.	17596	95182	Total.	13673	101865

The above table shows that the lowest average price of a pound of balata exported from British Guiana was 9.13 pence in 1885, and the highest, 14.17 pence, in 1888; while the lowest average price per pound exported from Dutch Guiana was 9.07 pence in 1889, and the highest, 18.14 pence in 1893 and 1896. It must, however, be taken into consideration that this calculation of price is based upon the declared value in the export harbors. On the other hand the selling price in the European markets, Liverpool, London, Marseilles, Rotterdam and Hamburg was considerably higher and, in London, varied during the last fifteen years for balata in sheets and blocks 1/1 to 2/6 per pound.

The principal difference between gutta percha and balata shows itself in the manner in which the two products are influenced by the air. While gutta percha, by the action of air and light, becomes rapidly resinous, hard and brittle, not only upon the surface, but also in the interior, if this action continues for some time, balata, under the same conditions, remains unaltered for a long period. At the ordinary temperature it is softer than gutta percha, and after cooling, does not acquire the same degree of solidity. On the whole it cools slowly, and when mixed with gutta percha, transmits this property to the mixture. When heated it diffuses the same odor as pure gutta percha which has been slowly heated under water and then brought to boiling. Its specific gravity is 1.05. It can be cut like gutta percha, but is

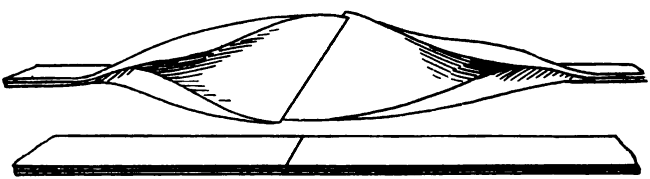
tougher. It dissolves completely in turpentine, but especially so in benzene and carbon disulphide when heated. Like rubber and gutta percha, it resists caustic alkalies and acts in the same manner towards hydrochloric acid. By sulphuric acid it is carbonized. At the ordinary temperature it forms a horn-like mass, but softens at 120° F., and in this state can be given any desired form.

When the commercial article is purified by washing in boiling water, to which a small quantity of acid has been added, and then in boiling alcohol, a mass is obtained which, when dissolved in carbon disulphide, filtered and evaporated, shows, according to Sperlich, the same composition as gutta percha namely: Carbon, 88.5; hydrogen, 11.3 per cent.

Crude balata is worked in a manner similar to gutta percha, the same apparatus and machines being used. In most cases, however, the manipulation is much simpler, because balata, as a rule, contains fewer impurities than gutta percha, and besides it is not used for articles for such delicate purposes as the latter. Frequently simple washing in a hollander suffices as a preparation for further working. Some varieties furnish, when vigorously kneaded, a very homogeneous material which, however, retains too much elasticity and remains adhesive. Purified balata is also less pliant than gutta percha and, without being mixed with the latter, can only be used for certain purposes. Unmixed it is not suitable for covering wires for the purpose of insulation, and even when mixed with

the best quality of gutta percha it is of less value for this purpose than pure gutta percha of even second quality. On the other hand, additions of balata to gutta percha, and even to rubber, are very proper to give both of them qualities desired for certain purposes. Unmixed balata is used for the preparation of matrices and moulds for galvanoplastic purposes, for shoe-soles, sweat-bands and particularly machine belts. For the manufacture of the latter it is especially suitable on account of its great toughness; but, like gutta percha belts, they must not be used in very warm rooms, as otherwise they become sticky. The manufacture of balata belts is analogous

FIG. 24.



to that of rubber belts. The best quality of strong cotton tissue is used for the purpose, and is treated with prepared mass in the spreading calender or spreading machine, then folded together to the required thickness, frequently provided with longitudinal seams, and then pressed either in that state or after it has received upon one or both sides a covering sheet. It is scarcely necessary to say that these belts do not require vulcanizing. The ends of this kind of belt can be joined together by a very sim-

ple joint, which is made as follows: Heat the two ends until they are sticky, then spread the belt out flat, Fig. 24, push the two ends so far one over the other that a cut made at an angle of 45° slopes both ends suitably towards each other, bring the edges $\frac{3}{4}$ to 1 inch over each other, press with an iron, replace the now jointed belt in its original folds and subject the joint to pressure. When the joint is cold the belt can be placed in position and runs without pounding or knocking, and hence is especially suitable for driving dynamo machines.

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